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ABSTRACT

This study of patterns of microcomputer-based instruction in elementary and secondary schools had three objectives: (1) to describe how teachers who were nominated by their peers as "unusually successful" in their microcomputer-based mathematics and science teaching use technology for instruction; (2) to describe how these uses vary as a function of teacher characteristics and other background variables; and (3) to recommend policies for educating teachers in the instructional uses of microcomputers and for devising courseware that serves pedagogical aims. A total of 60 teachers--40 elementary and 20 secondary--in 25 districts and 49 schools in the state of California were interviewed. Schools varied in the number of microcomputers available for instruction (1 to 55, with an average of about 12), and in the resources they provided for microcomputer-based instruction. Based on 16 variables of instructional characteristics underlying microcomputer-based instruction, four homogeneous clusters of teachers were identified: orchestration (N=18), enrichment (N-23), adjunct instruction (N=14), and drill and practice (N=5). Analysis of the data indicates that, although teacher attitudes toward microcomputers were not related to the patterns of microcomputer-based instruction that were identified, all teachers held uniformly positive attitudes. Teacher knowledge about microcomputers was also unrelated to the average amount of coursework taken in mathematics, but the amount of science taken as an undergraduate did reflect positively on instructional use. Recommendations are presented for staff development and the characteristics of teacher-friendly courseware are discussed. Appendices include the interview guides and questionnaires used as well as discussions of methodological considerations and modes of microcomputer-based instruction. A list of references completes the document. (JB)

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PREFACE

At a time when American education is perceived as less than excellent, microcomputers are viewed as holding great promise for improving classroom instruction by supplementing teaching capability. Several problems impede their widespread implementation, however. These problems derive, in part, from a lack of knowledge of how best to coordinate microcomputer-based instruction with ongoing classroom teaching.

This study of "'Successful' Teachers' Patterns of Microcomputer-based Mathematics and Science Instruction," sponsored by the National Institute of Education (Contract No. 400-82-0006) and The Rand Corporation, had three objectives:

- To describe how teachers who were nominated by their peers as "successful" microcomputer-using teachers use technology for instruction.
- To describe how these uses vary as a function of teacher characteristics (e.g., attitudes, knowledge) and other contextual variables (e.g., district, school, classroom).
- To recommend policies based on these teachers' suggestions as to staff development for educating teachers in the instructional uses of microcomputers and for devising courseware that serves pedagogical aims.

This report should be of interest to national, state, and local-education policymakers, educators, and courseware developers. Pursuing the objectives noted can improve the understanding of how microcomputers may be coordinated with ongoing teaching, how teachers may be educated in their uses, and how courseware may be made more "teacher-friendly."

For a detailed summary of the study findings, see *Teaching Mathematics and Science: Patterns of Microcomputer Use*, R-3180-NIE/RC, by Richard J. Shavelson, John D. Winkler, Cathleen Stasz, Werner Feibel, Abby E. Robyn, and Steven Shaha.

SUMMARY

This study addressed the following questions regarding microcomputer-based instruction in elementary and secondary schools: (1) What patterns of microcomputer-based mathematics and science instruction are employed by public school teachers nominated as unusually successful in microcomputer use? (2) Are these patterns related to (i) district and school policies for microcomputers? (ii) organizational and compositional contexts of classrooms? (iii) teachers' attitudes toward computers? (iv) teachers' subject-matter and computer knowledge? (3) What do these teachers recommend about (i) educating other teachers to incorporate microcomputer-based instruction into their teaching repertoire, and (ii) improving the quality of instructional courseware?

STUDY SAMPLE AND METHODS

We sought to answer these questions during the winter and spring of 1983 through an intensive study of 40 elementary and 20 secondary teachers who were nominated as exemplary users of microcomputers in mathematics and science instruction. Their general characteristics were as follows: (a) 2 to 38 years of teaching experience with an average of 15.8 years; and (b) 39 percent of their undergraduate coursework in science and mathematics, 21 percent in the humanities, and 18 percent in the social sciences.

These teachers were located in 25 districts and 49 schools in the state of California. The districts and schools varied considerably. Fourteen of the districts were unified school districts, 7 were elementary, and 4 were secondary. Students served ranged from 5 to about 90 percent minority, and their performance on measures of statewide reading and mathematics achievement covered the first to fifth quintiles. Schools also varied in the number of microcomputers available for instruction (1 to 55 with an average of about 12) and in the resources they provided for microcomputer-based instruction.

Fieldwork consisted of interviews with teachers and school and district administrators for about an hour each, and included observations of each teacher's microcomputer-based instruction for at least one class period of about 50 minutes. In a companion study funded by The Rand Corporation, biographical information was obtained on microcomputer-using teachers including the 60 participating in this study. All told, data were collected on district and school policies and support for microcomputers; organizational and compositional contexts of the classrooms; teachers' instructional decisions, practices, and microcomputer uses; their subject-matter and computer knowledge; and their attitudes toward computers.

PATTERNS OF MICROCOMPUTER-BASED INSTRUCTION

In order to identify *patterns* of microcomputer-based instruction employed by teachers nominated as unusually successful, we (1) identified instructional characteristics that underlie successful microcomputer-based instruction; (2) created a profile for each teacher according to those characteristics; (3) formed statistically homogeneous *clusters* of teachers using these characteristics; (4) interpreted the resulting clusters on the basis of the profile; and (5) described the clusters of teachers using other variables related to instructional decisions and practices regarding microcomputer use.

Teacher Profile

We defined instructional microcomputer use as the *appropriate integration* of *microcomputer-based learning activities* with *teachers' instructional goals* and with the *ongoing curriculum*, which changes and improves on the basis of *feedback* that indicates whether desired outcomes are achieved. Based on this definition, we characterized teachers' microcomputer-based instruction according to 16 variables. Five variables related to teachers' goals for students (e.g., whether they stressed microcomputer use for *mastery* of basic skills). Five variables characterized how microcomputers were linked with the ongoing curriculum (e.g., coordination between computer-based activities and other learning activities). Three variables indexed microcomputer-based instructional activities such as instructional modes (e.g., drill and practice, tutorial, simulation, and the grouping of students for computer use). Two variables characterized the appropriateness of microcomputer use (i.e., teachers' and field staff's assessment of success of use). Finally, we determined whether teachers had modified their instruction based on feedback.

Interpretation of Clusters

Four clusters emerged from the analysis. Cluster 1 (n=18), called "orchestration," represented the widest variety of instructional applications closely linked to regular curricular activities. Cluster 2 (n=23), termed "enrichment," capitalized on available courseware to familiarize students with microcomputers and, as a consequence, integrated microcomputer activities least with subject matter and other classroom activities. Cluster 3 (n=14), dubbed "adjunct instruction," used the microcomputer to selectively augment lessons in mathematics and science. Cluster 4 (n=5), labeled "drill and practice," stressed this instructional mode and basic-skill objectives, and tied microcomputer-based instruction closely to the curriculum and classroom activities. Below, the four clusters are described in more detail.

Orchestration Cluster. Cluster 1 was termed "orchestration" because teachers in this cluster stressed both cognitive and basic-skills goals, as well as microcomputer use as a goal in and of itself; used a variety of instructional modes to meet these goals (e.g., drill and practice, tutorial, simulation, microworld, game); integrated the content of microcomputer-based instruction with the ongoing curriculum, and coordinated microcomputer activities with other instructional activities; changed their uses based on feedback from students; and, not surprisingly, were evaluated as most successful in their use of microcomputer-based instruction during field visits by our staff and by themselves. Of the four clusters, the orchestration cluster represented the fullest instructional use of microcomputers by virtue of using microcomputers in ways set forth in our definition above.

Enrichment Cluster. Teachers in the enrichment cluster were least inclined to integrate microcomputer-based instruction with the ongoing curriculum, to coordinate this activity with other classroom activities, or to use the microcomputer to help students master basic skills. Thus, they tended to use microcomputers less for instruction than teachers in clusters 1 and 4. However, teachers in this cluster were most likely to use the microcomputer in instruction in subjects other than mathematics or science (e.g., word-processing). And more teachers in this cluster than in clusters 3 and 4 encouraged microcomputer use in its own right. This suggests that their computer use was somewhat ad hoc and served as an end in itself more than as an instructional means. Although these teachers, on average, viewed themselves as successful in microcomputer-based instruction as teachers in the orchestration cluster, staff field evaluations were less positive.

Adjunct-instruction Cluster. Teachers in cluster 3 were distinguished by their grouping decisions--they provided instruction using microcomputers to students in groups of two or more. Moreover, they confined microcomputer use to mathematics or science subjects, emphasizing *cognitive goals*, in a catch-as-catch-can manner that was not as closely integrated with the ongoing curriculum as was common among teachers in clusters 1 and 4. Unlike teachers in cluster 2 who try to use the microcomputer to provide a wide range, even if a somewhat limited amount, of instruction, the approach of the cluster 3 teachers appears to be to selectively augment certain lessons, and not to view microcomputer use as a goal in itself.

Drill and Practice Cluster. The number of teachers in cluster 4 was small (roughly 8 percent of the sample), but the teachers were very homogeneous in their use of microcomputer-based instruction. Each used drill and practice extensively and almost exclusively to achieve mastery of basic skills in mathematics or science. Microcomputer-based instruction was not used for the acquisition of higher-order, conceptual skills, nor were microcomputers used to develop skills in using information technology. Computer-based instruction was delivered to students individually, was closely integrated with the ongoing curriculum, and was closely coordinated with other classroom activities. These teachers had not changed their computer use since implementation.

Other Instructional Decisions and Practices

Different patterns of microcomputer-based instruction might also be associated with other instructional decisions and practices, including: (a) allocation of time for microcomputer use, (b) use of specific instructional modes, (c) rules for microcomputer use, and (d) strategies for grouping students. Information on these instructional practices elaborated our understanding of alternative patterns of instructional use.

Among all of these variables, the use of particular modes was associated with cluster membership. Teachers labeled as "orchestrators" (cluster 1) were distinguished by their use of multiple instructional modes. The differences lay in this cluster's use of tutorials, simulations, and microworlds. The fact that roughly three-fourths or more of the teachers in each cluster used drill and practice is significant, for at least two reasons. First, it reflects the fact that this type of courseware is most readily available. Second, it indicates that, although the clusters represent distinct patterns of use, none systematically excludes this mode of instruction.

Indeed, this finding highlights the fact that similarities among clusters are as informative as the differences. In general, the teachers did not stress the use of microcomputers for motivating students or for keeping students' records or testing them. They typically assigned equal amounts of time at the microcomputer to all students--about an hour per week. Most had established rules regarding the operation of the computer and regarding talking while working with the computer. Most teachers assigned material to students on the microcomputer by matching content/difficulty and (less typically) by matching instructional mode to student need; they were also opportunistic, assigning students to special software when it became available.

TEACHERS' ATTITUDES, KNOWLEDGE, AND TEACHING CONTEXTS

We examined whether differences in the patterns of microcomputer-based instruction were related to teachers' attitudes toward computers, as well as to their subject-matter and computer knowledge. These issues bear on policies regarding teacher selection and training. For example, if relationships are found, information on teachers' attitudes and subject-matter background might, among other kinds of information, enter into a district's decision about the types of teachers to hire or train. Moreover, information about the nature of teachers' computer knowledge might be used, along with other information, to establish a curriculum for preservice or inservice education.

Individual differences among teachers in their attitudes and knowledge cannot, however, account for all the variability in microcomputer-based instruction. There are contextual factors that encourage, discourage, or set limits on the kinds and range of instructional uses teachers may employ. District policies regarding amounts and kinds of hardware and courseware might influence computer use. School support and encouragement might affect use. And the students served might affect the modes of instruction employed. Selection and training decisions, then, might depend on the particular context in which instruction is delivered.

Teachers' Attitudes

Teachers' attitudes toward microcomputers were unrelated to the patterns of microcomputer-based instruction that we identified. All teachers held uniformly positive attitudes. In a group of teachers nominated as unusually successful in their microcomputer use, this finding was not unexpected.

Teachers' Subject-Matter Knowledge

A teacher's subject-matter knowledge, especially in mathematics and science, might reasonably be expected to influence patterns of microcomputer-based instruction, especially in those subject matters. This seems to be what some politicians and policymakers had in mind when mathematics and science teachers were suggested as the potential leaders of the microcomputer movement in education.

In lieu of direct and extensive testing of teachers' subject-matter knowledge, something not feasible in this study, we settled for a proxy measure of knowledge. Teachers were asked to indicate the percent of their undergraduate coursework spent in science, mathematics, computer science, social science, humanities, and education. We then examined the relations between these indicators of knowledge and patterns of microcomputer-based instruction.

By and large, our findings corroborated those of research on the relation between teacher knowledge and student outcomes: there were not systematic (statistically significant) differences among patterns of use in terms of the average percent of coursework taken in mathematics, computer science, social science, humanities, and education.

Instructional use, however, systematically varied as a function of the amount of science taken as an undergraduate. Teachers in the adjunct instruction and especially in the drill and practice cluster took, on average, considerably more coursework in science than did teachers in the orchestration and enrichment clusters. In contrast, the orchestrators tended to take, on average, the least amount of coursework in science and the most in mathematics and social science.

Teachers' Computer Knowledge

One might expect that variations in knowledge of computer hardware and software would be related to different patterns of microcomputer-based instruction. More knowledgeable teachers might use a wider range of instructional modes or might select courseware that makes fuller use of the hardware's capabilities.

As with subject-matter knowledge, we sought a measure of teachers' knowledge that could be obtained easily and unobtrusively. We asked teachers how extensively they had used computer hardware and courseware. We also asked whether they had served as a resource person for their schools or as an instructor for staff development. Finally, we asked how many programming languages they had used. In addition, interviewers rated each teacher's courseware and hardware knowledge.

Patterns of microcomputer-based instruction proved to be unrelated to teachers' experience in using microcomputers, in teaching other teachers about them, or in their ability to write in one or more computer languages. Patterns of instructional use did, however, systematically vary as a function of the interviewers' ratings of teachers' *courseware* knowledge. Teachers in the orchestration cluster were rated as significantly more knowledgeable about courseware than teachers in the drill and practice cluster. This finding is, perhaps, not unexpected since the drillers primarily used just one type of courseware whereas the orchestrators were distinguished by their uses of multiple modes of microcomputer-based instruction.

DISTRICT AND SCHOOL CONTEXT

We collected data on the extent to which the 25 districts supported the implementation and the instructional use of microcomputers, and on the extent to which the 49 schools (principals) supported and provided incentives for microcomputer use. The central question behind these analyses was: "To what extent, if any, were district and school context factors related to the different patterns of instructional use we had observed?"

Without exception, the answer to this question was *none*. Across clusters, most teachers were found, not surprisingly, in districts where (a) the impetus for computers came from teachers, (b) microcomputers were supported, at least to some extent, but (c) microcomputers were not included in the district budget as a line item. About half the teachers were drawn from schools that provided personnel support for computer use, and roughly two-thirds were offered some kind of incentive for using computers--primarily release time to attend computer workshops. By and large, the responsibility for implementing microcomputer-based instruction fell squarely on the shoulders of the teachers.

CLASSROOM CONTEXT

The organization and composition of students in classrooms profoundly affects instructional processes and outcomes and thus might also be expected to affect microcomputer-based instruction. For example, warnings and recent findings have suggested that low achieving, minority students may be more likely to receive drill and practice and that high ability majority students may be more likely to receive creative problem-solving instruction on the computer.

We collected data in interviews and observations on the number of microcomputers available for instruction and their proximity to the teachers' classrooms. Because elementary schools are organized around self-contained classrooms and secondary-school classrooms are organized by subject matter, we included this grade-level distinction as well. Teachers estimated the percent of minority students in their classes and the ability level of their students.

Patterns of microcomputer-based instruction proved to be unrelated to the organizational variables. In striking contrast was the finding that patterns of microcomputer-based instruction were related to classroom composition. Classrooms with students above average in ability and low in percent of minorities tended to be taught by teachers characterized as "orchestrating" the ongoing curriculum with a wide variety of microcomputer-based instructional modes stressing both skill acquisition and conceptual knowledge. As the ability level decreased and percent minority increased, microcomputer-based instruction tended toward enrichment and adjunct instruction. The five classrooms with a high percentage of minority students low in ability employed microcomputers to deliver drill and practice on the basic skills taught in class. If the medium is the message, the message delivered to students of "drill and practice" teachers is substantially different from the message received by students of "orchestrators."

RECOMMENDATIONS FOR STAFF DEVELOPMENT

Based on a review of the staff-development literature, case studies of staff development for instructional computer use, teacher surveys, recommendations obtained from the teachers in our study, and on our observations of their microcomputer-based instruction, we derived a set of recommendations for staff development in microcomputer-based instruction. Many of these recommendations have already been incorporated into one or another staff-development program; others are rarely included. Most might be implemented in different ways, reflecting, in part, school district philosophy and resources, and teachers' needs, interests, and classroom contexts. These recommendations are not strict prescriptions; adaptation to local needs and resources is advised.

Recommendations for the Content of Staff Development

The basic staff development course probably should include the following topics: operation of the microcomputer, selection and evaluation of courseware, instructional uses of microcomputers, computer literacy, and methods for integrating microcomputers with the ongoing curriculum. This course might also include computer programming, at least to the degree that programming either helps teachers understand how the computer operates, or meets the needs of particular teachers such as mathematics teachers.

RECOMMENDATIONS FOR THE ORGANIZATION OF STAFF DEVELOPMENT

We recommend that a basic staff development course on microcomputer-based instruction be organized such that initiation of the activity is a collaborative effort of teachers and administrators. Teachers' participation would be voluntary. The objectives for the activity should be well articulated, based on input from both participants and providers. The content of the staff development activity should be concrete with as much hands-on experience as possible. Not all teachers need or should receive identical training, however. Training instead should be geared to individuals' knowledge and experience.

The duration of the activity should be sufficient to permit teachers to learn, practice, master, and apply the skills imparted. The staff development activity should be followed up with classroom support as training is adapted to practice.

Finally, we recommend inclusion of valued incentives for all phases of the activity. These might include monetary factors, work-related factors (e.g., release time), or both.

RECOMMENDATIONS FOR "TEACHER-FRIENDLY" COURSEWARE

Based on a review of research on courseware types and methods, existing evaluation guides, evaluations of courseware obtained from teachers in our study, and our experience with educational software, we derived a set of recommendations for improving the usefulness and value of educational courseware. Some of the recommendations already influence current courseware design, but much progress can still be made to make courseware more "teacher friendly."

Pedagogical Attributes of Courseware and Teachers' Roles in Its Design

Courseware with greater pedagogical value can result if teachers play an expanded role in its design and development. Along with computer experts and others, teachers probably should be involved in the development of courseware instructions, documentation, and ancillary materials. We also recommend that teachers play a role in identifying prerequisites for mastering the concepts and skills to be taught, as well as appropriate means for communicating the subject matter (e.g., tutorials or simulations). They could help assure that the courseware content contains substance and is error free; the courseware engages appropriate thinking and problem-solving skills; the level, pace, and presentation are proper for the intended audience; and student participation elicited by the program is likely to be active. They might help determine how the courseware will provide diagnostics and feedback because they are aware of common misconceptions held by students and possible didactic paths for correcting them. Finally, because teachers are familiar with curricula in their subject-matter areas, they could assist in designing courseware to coordinate with other curricular materials that may be available.

Evaluation and Revision

During its development, we recommend several evaluation and revision cycles to help identify procedural and conceptual problems students encounter while interacting with the program and problems encountered with program-generated instructions, "help" facilities, and documentation. Similarly, testing the program with multiple audiences (students, teachers, subject-matter experts) should uncover flaws and significantly decrease the probability of the program "crashing."

Strategy for System Design

We recommend that courseware design be carried out by a team including teachers, subject-matter experts, behavioral scientists, and programmers. The design process should encompass strategies for program writing that make full use of the computer's capabilities.

Reviewing and Copying Courseware

To address teachers' needs for examination of alternative courseware, we suggest "courseware libraries." Such libraries would permit teachers, in person or via telecommunications hookup, to review courseware, its documentation, and others' evaluations of it. The library might be set up by publishers, state education agencies, or districts. The library concept seems to have the merit of making courseware widely available for teachers to review while protecting the copyright of the publisher.

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I. MICROCOMPUTERS IN THE PURSUIT OF EDUCATIONAL EXCELLENCE

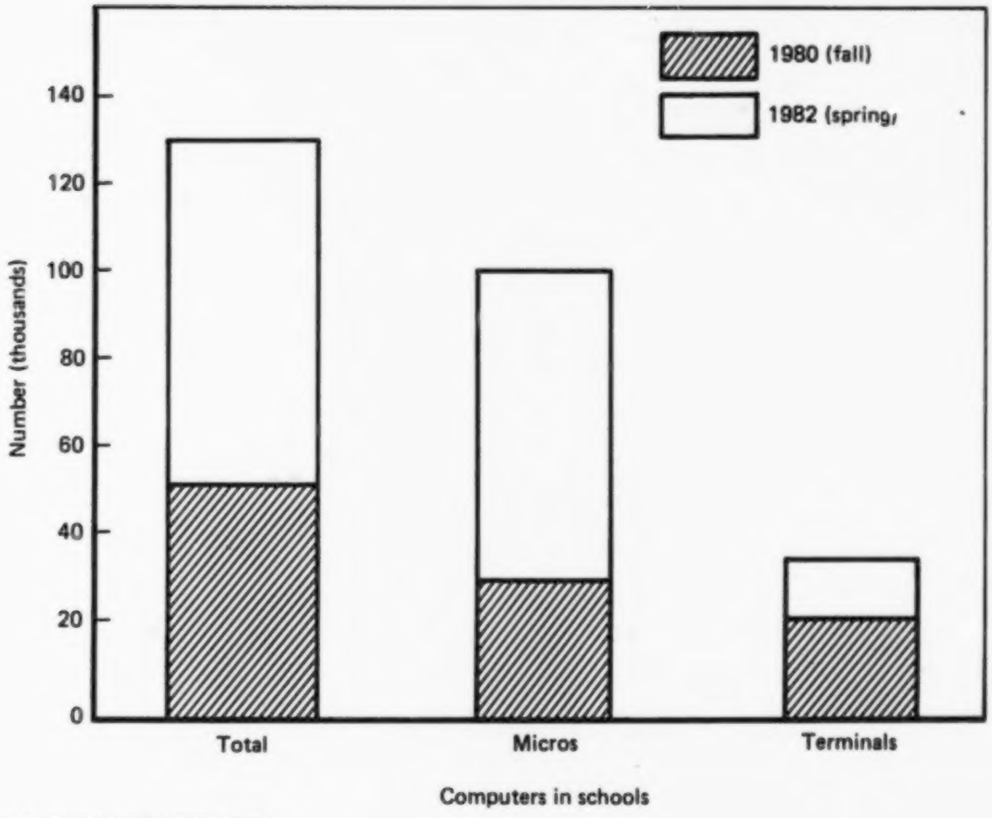
INTRODUCTION

Educational quality has emerged as one of the nation's most pressing domestic issues of the 1980s. The blue-ribbon National Commission on Excellence in Education (1983, p. 5) gave credence to this concern: "[T]he educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people." That the nation's schools have slipped into mediocrity is more than hyperbole. The Commission cites a wide variety of indicators: The United States lags behind other nations in achievement-test performance; approximately 23 million Americans are functionally illiterate; and, business and military leaders complain that they have to provide their personnel with remedial education and training in basic skills.

The overriding policy question today no longer asks whether there is a crisis in American education, but asks what can be done to improve its current state. The responses of federal and state policymakers, educators, and the general public have consistently included the idea of capitalizing on recent technological innovations, in particular microcomputers. Three interrelated factors, however, currently limit the potential contribution of technology to education: the unavailability of computers, a lack of knowledge about how best to educate teachers in the instructional uses of computers, and a shortage of high-quality instructional software (termed "*courseware*") to accompany local curricula (Office of Technology Assessment (OTA), 1982).

Availability of Computers

Between the fall of 1980 and the spring of 1982, the number of microcomputers in public schools increased a whopping 230 percent, and their number continues to increase today (National Center for Education Statistics (NCES), 1982; OTA, 1982; see Figure 1.1). In absolute figures, the number of microcomputers jumped from approximately 30,000 in the fall of 1980 to roughly 102,000 in the spring of 1982 (NCES,



SOURCE: NCES (1980, 1982)

Fig. 1.1 -- Numbers and types of computers in elementary and secondary schools: 1980 and 1982

1980, 1982). By the year 1992, the Office of Technology Assessment projects that roughly 4 million microcomputers will be installed in schools (Figure 1.2).

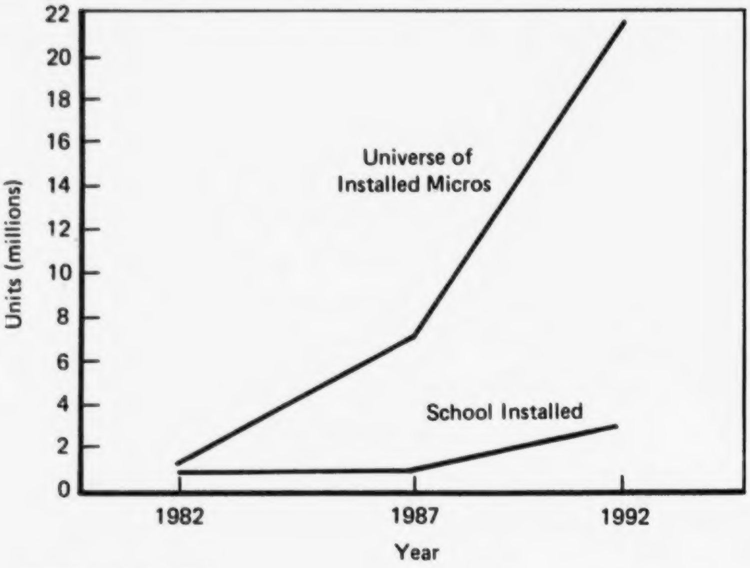
However, these numbers are less impressive upon second thought. First, computer installation in schools will not keep pace with the overall expansion of installations during the next nine years (Figure 1.2; cf. Pogrow, 1983). Second, although the numbers may appear large, the school population is much larger. The 100,000 microcomputers translate into less than one for every school, or one for every 20 classrooms, or one for every 420 students in the spring of 1982. Even with current state legislation (e.g., California's Apple bill) and pending federal legislation providing a tax break to companies donating microcomputers to schools, the cost of hardware remains a prohibitive barrier to widespread infusion of computers in schools. Thus, microcomputers are not readily accessible in large numbers to most classrooms; the time available for student use is limited; and, the educational applications of microcomputers do not come close to their potential.

Training Needs for Teachers and Availability of Courseware

Even if microcomputers were widely available in schools, important problems would still remain. Few teachers have been educated to use them instructionally and the amount, quality, and coverage of courseware is inadequate at present. With respect to teachers, the Office of Technology Assessment (1982, pp. 9-10) concluded that:

> Widespread use of technology in the classroom will require that teachers be trained both in its use and in the production of good curriculum materials. Too few teachers are so qualified today.... Furthermore, there is little evidence that most of the teacher training colleges in the United States are providing adequate instruction to new teachers in the use of information technology.

The need for quality courseware is no less urgent. An estimated 50,000 schools reported that courseware was an (unavailable) necessity for initiating or improving computer-based education (NCES 1982; cf.



SOURCE: OTA (1983)

Fig. 1.2 -- Projected number of installed micros: 1982-1992

OTA, 1982). The Office of Technology Assessment (1982) cited a number of reasons for the lack of quality courseware: (a) Curriculum providers have not yet learned to use the new technology to its full advantage; (b) production of high-quality courseware is expensive; estimates of development costs are often in the thousands of dollars for one hour of running material (Shavelson & Winkler, 1982) and $250,000 per major courseware package (OTA, 1982); (c) programmers and curriculum experts needed to produce quality courseware are in short supply, and when curriculum experts are available, they are often left out of the development process; and, (d) major software providers are reluctant to enter an economically uncertain market that is tremendously broad, encompassing numerous curricular subjects at various grade levels conforming to unique requirements in every state.

STUDY OBJECTIVES

In the end, the shortage of microcomputers in schools derives from *cost* considerations at a time of fiscal retrenchment, whereas limitations in teacher education and quality courseware arise out of gaps in our *knowledge* of how to coordinate technological innovations with teaching. Assuming that microcomputers will become increasingly available in schools, this study seeks to narrow knowledge gaps. Our objective is twofold: (1) to describe model microcomputer-based instructional practices by studying teachers who are considered by their peers, school officials, and/or computer educators as "unusually successful" in their microcomputer-based mathematics and science teaching; and, based on data from these teachers and findings of other research, (2) to make recommendations for educating teachers in microcomputer-based instruction, and for improving the quality of courseware.

We undertake this descriptive study with some trepidation, recognizing that with increased availability of microcomputers and improved courseware and teacher education in computer use, these models may rapidly become outdated. Nevertheless, we believe that the current knowledge gap should be filled even if the findings may be timebound. An alternative would have been to posit, on the basis of theory and intelligent projections regarding such things as breakthroughs in courseware design, a "futuristic" ideal for microcomputer-based instruction. We chose to characterize today's state-of-the-art, however, because we feel this approach will better deal with current pressing needs of teachers, administrators and teacher educators.

With these objectives in mind, we conducted fieldwork with teachers nominated as "successful" computer-using science and mathematics instructors in both elementary and secondary schools. This fieldwork, the procedures for which are described in Section II, was guided by the following assumptions:

- School-district policies for implementing and supporting instructional uses of microcomputers, along with characteristics of the community and students served (e.g., socioeconomic status) would influence the number of microcomputers available and the ways teachers use them for instruction.
- Instructional uses of microcomputers would be influenced by certain *teacher* characteristics such as their attitudes about computers in education and society, their knowledge about the computers themselves, and their subject-matter knowledge.
- District and school policies, and characteristics of students served would moderate how teachers' attitudes and knowledge influence their teaching practices with microcomputers.
- Recommendations regarding training and courseware would depend upon relationships among teachers' instructional practices, individual characteristics, and teaching contexts.

Study Design

The above assumptions imply relationships among four categories of variables: (a) teachers' *instructional use* of microcomputers; (b) teachers' *knowledge* of computers and subject matter; (c) teachers' *attitudes* toward computers; and (d) the *contexts* (districts, schools and classrooms) in which teaching occurs. Our initial conception of this system of variables is presented in Figure 1.3, in which the boxes identify the types of variables and the arrows indicate functional

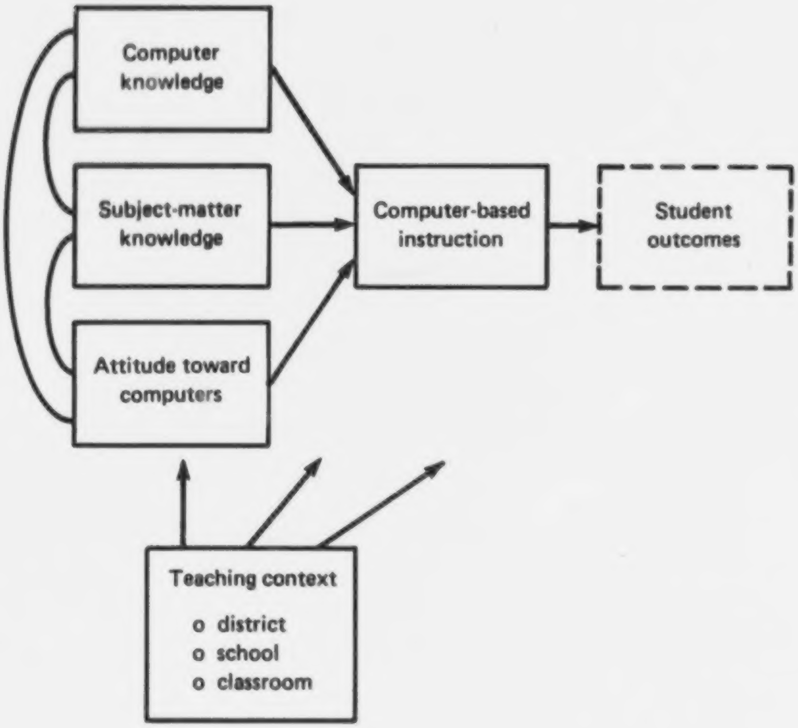

Computer knowledge
Subject-matter knowledge
Attitude toward computers
Computer-based instruction
Student outcomes
Teaching context
o district
o school
o classroom

Fig. 1.3 -- Conceptual framework

relations. We expected the teaching context, especially district and school policies for selecting teachers and supporting microcomputer use, the characteristics of the students, and other unidentified factors to influence teachers' attitudes, computer knowledge, and content knowledge. Attitudes and knowledge were expected to be interrelated; and context, attitude, and knowledge were expected to distinguish among patterns of microcomputer-based instruction. We characterized patterns of instructional uses by a set of instructional planning activities and teaching practices. Finally, different patterns of microcomputer-based instruction were expected to lead to differences in student outcomes. However, collection of student outcome data was beyond the scope of this study.

To obtain the information necessary to examine this preliminary conceptualization, researchers from The Rand Corporation and from the Educational Technology Center at the University of California, Irvine, conducted fieldwork with 60 elementary and secondary teachers who use microcomputers in their mathematics or science instruction in 25 districts and 49 schools in California. Fieldwork consisted of interviews with teachers and district and school administrators, and of observations of microcomputer-based instruction. Biographical data were also obtained on these microcomputer-using teachers in a parallel study funded by The Rand Corporation.

More specifically, for each component of Figure 1.3, we collected data on several variables. For example, district staff were interviewed to collect information on districts' reasons for implementing microcomputers, and policies about, and provisions for, funding and supporting their instructional use. Principals were interviewed to obtain information about school support for microcomputer use and incentives used to stimulate and improve their quality of use. Interviews with teachers, observations of their classes, and biographical questions provided data on attitudes, knowledge, and microcomputer-based instruction.

Major Analyses and Organization of the Note

This Note presents data analyses that, by examining the conceptualization presented in Figure 1.3, serve to: (a) characterize the state of instructional computer use in schools (within sampling limitations) and (b) identify factors on which teachers might be selected for instructional computer use (e.g., attitudes, subject-matter knowledge), trained for instructional computer use (e.g., computer knowledge), or both in order to provide one or another model pattern of microcomputer-based instruction. We also report analyses underlying recommendations for educating teachers to use microcomputers as part of their instructional program, and for developing courseware that is more "teacher-friendly," that is, pedagogically sound and easy to use for instruction in school environments.

First, however, we discuss the methods used in planning and performing the current research. Section II describes the data collection procedures in detail and describes the characteristics of the sample of districts, schools, and teachers.

An important component of our analyses is the characterization of instructional microcomputer use, because it provides the basis for distinguishing among teachers' practices, recommendations for training and courseware, and contextual influences. Section III presents our definition of sound pedagogical uses of microcomputers based on the theoretical framework that guides this research. Using variables suggested by this definition, we distinguish among patterns of microcomputer-based instruction, by placing teachers into homogeneous groups on the basis of their standing on these variables. Each group of teachers was then characterized as to their specific instructional decisions and practices.

We examine the relationship between alternate patterns of instructional use and context, attitude, and knowledge (subject-matter and computer) variables in Section IV.

In Section V, we examine the literature on staff development, in particular what has been recommended for training programs to provide teachers with skills needed to use microcomputers instructionally. Next, teachers' recommendations for the content, timing, location, and incentives of staff development are examined. The section is concluded by a set of recommendations for preservice and inservice education.

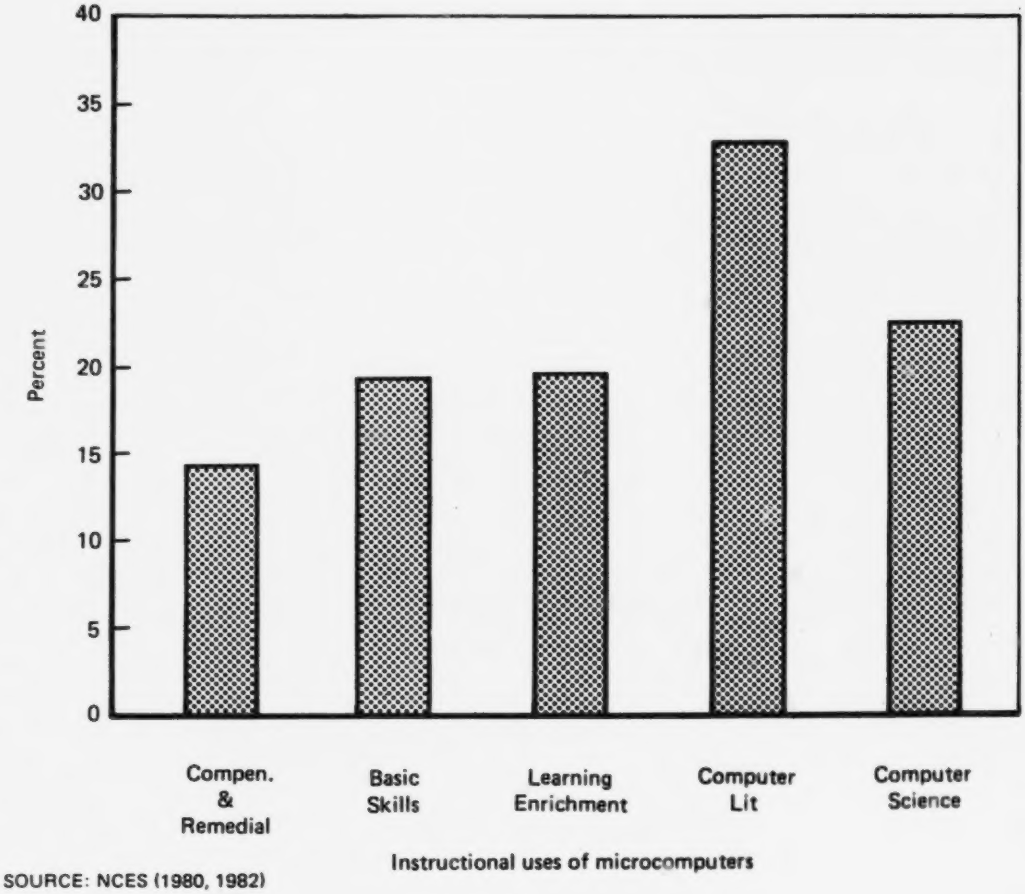
Section VI advances recommendations for developing "teacher-friendly" courseware. We arrive at these guidelines by reviewing pertinent literature, examining recommendations the teachers made on the basis of their uses of computers, and drawing on our observations of and data on instructional uses of microcomputers.

II. THE SEARCH FOR SUCCESSFUL COMPUTER-USING TEACHERS: SAMPLE AND METHODS

Curiously, when politicians, educational bureaucrats, and the media speak of the "computer revolution" and its place in the nation's quest for educational excellence, seldom are teachers mentioned, unless to say they are inadequately prepared for the "revolution" and need to be "trained." Indeed, national statistics, such as those in Figure 2.1, promote the impression that the revolution has arrived and that a learning environment now exists in schools in which students sit before a bank of microcomputers receiving instruction--be it drill and practice for remediation or development of basic skills, learning enrichment, or computer literacy.

However, this picture inaccurately represents the teaching environments for most instruction that includes microcomputers. What many politicians, educational bureaucrats and the media are apparently unaware of is that most computer-based instruction has been initiated by *teachers*--"computer buffs" and their followers--and that these activities occur largely unaided by financial or expert resources, adequate numbers of microcomputers, and quality courseware. The extent to which progress toward national goals of literacy and computer-based instruction are met actually depends on how well teachers are able to adapt, not to learning environments that are idealized, but to ones that contain relatively few microcomputers and less than optimal courseware (cf. Becker, 1984).

Prescriptions for improving training and courseware for instructional use of microcomputers, then, begin with the recognition that the current climate for microcomputer-based instruction is far from optimal. Progress can be made by assuming that, despite the limitations: (a) some teachers who are currently using microcomputers to deliver instruction have been successful, and (b) knowledge gained about their backgrounds, teaching decisions and practices, and recommendations for training and courseware can help fill the current knowledge gap. By filling this gap, we are in a better position to identify what teachers



SOURCE: NCES (1980, 1982)

Fig. 2.1 -- Percent of elementary and secondary schools with microcomputers using different kinds of instruction, Spring 1982

need to know to use microcomputers successfully in their instruction and what improvements in courseware and courseware development strategies are needed to enhance its quality and usefulness.

The study, then, sought and described teachers who were recognized as successful in using microcomputers. In this section, we present our methods for finding and obtaining data from these teachers. First, sampling procedures are presented followed by our data collection procedures and instruments. Finally, we describe the teachers, schools, and districts that participated in this study.

SAMPLE SELECTION

Original Sampling Plan

The fact that our initial research design was significantly changed during the course of the study reflects an important finding of the study and so a brief recount of its history is in order. The study was originally conceived as a case study of "successful" teachers' instructional computer uses and how these uses varied as a function of individual differences among teachers and teaching contexts (e.g., implementation and support policies at the district and school levels; students served within the classroom). We planned to search for successful computer-using teachers by choosing districts and schools where microcomputers were used for instruction in mathematics or science and then by selecting teacher respondents through nominations from administrative staff. Districts were to be stratified in order to provide variation on important characteristics, such as method of implementation (e.g., administrative decision or "grass-roots" initiation), presence of support policies and staff-development opportunities, and student and community characteristics. The study was to be limited to five school districts in California.[1]

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[1] The sample was confined to California for budgetary reasons. Nevertheless, prior research indicated that sufficient diversity of administrative policies, technological sophistication, and computer-based educational programs would be found in California, and that computer use within the state does not differ significantly from that found nationally (Chambers and Bork, 1980).

The sample was also restricted to public schools and regular classroom instruction. Within each of these five districts, two teachers--nominated by county and district staff, principals, and their peers as unusually successful in using microcomputers instructionally--were to be selected in each of two schools at the elementary, junior- and senior-high levels. All told, we expected to interview and observe 60 teachers (5x2x2x3), and to interview 30 principals (5x1x2x3), and 5 district staff responsible for microcomputers.

This hierarchical, top down sampling plan proved to be totally unrealistic, even in a state touted for pioneering the microcomputer industry and implementing these computers in the schools of "Silicon Valley." Our initial contacts with districts, schools, and teachers indicated that while microcomputers were used occasionally to teach programming or foster "computer literacy," they were used sparsely and infrequently for mathematics or science *instruction*. Thus, sufficient numbers of computer-using teachers could not be found in 5 districts and 30 schools to satisfy our initial sampling criteria. Moreover, computer-using teachers described as "successful" seemed to vanish from the classroom to administrative positions responsible for coordinating district computer use or to positions in private industry. We termed this phenomenon the "*vanishing computer-using teacher*."

Modified Sampling Plan

The sampling plan, then, was turned around and we first sought to locate "successful" microcomputer-using teachers engaged in mathematics or science instruction in California [redacted] schools. Once found, we then ascertained characteristics of the teacher's district and school. Thus, teachers became the primary sampling unit, and we relied on a "snowball" procedure that solicited nominations of highly regarded teachers from experts in the field--officials in government and education; administrators of educational computing organizations; district, school, and teacher contacts.

Suggestions were followed up through direct telephone contacts and successive screening of candidates, districts, and schools. Teachers nominated as "successful" or exemplary were invited to participate if they fulfilled the minimal criteria that they currently used microcomputers as part of regular classroom instruction in mathematics or science and were responsible for determining the content and form of the microcomputer-based learning activities.

We attempted to achieve an optimal mix among curriculum (mathematics and science), grade level (elementary and secondary), student characteristics (ability and socioeconomic level), and the amount and kind of district support for classroom microcomputer use. However, in practice, our selection of teachers, schools, and districts was driven in large part by our ability to locate elementary and secondary teachers of mathematics or science who fulfilled even these minimal selection criteria. Nonetheless, given the wide dispersion of respondents qualified to participate in the study, we achieved considerable diversity in instructional context. We ended up sampling five times as many districts (25) as planned and over one and a half times as many schools (49) in order to study the instructional computer uses of 60 teachers.

DATA COLLECTION PROCEDURES

Guiding Principles

The general principles that guided the data collection were that the research be *relational, field-based*, and *naturalistic*. The major goals--to describe patterns of microcomputer-based instruction and to make recommendations for improving teacher education and courseware--suggested that the study ought to relate patterns of instructional practices to characteristics of teachers (e.g., knowledge; attitudes) and learning contexts (e.g., district and school support policies). Furthermore, because the phenomenon concerned classroom teaching practices, it seemed imperative that the study be conducted in the classrooms and schools of the respondents, in ways that accounted for relationships among variables as they actually coexist.

However, performing research that is both relational and naturalistic implies some conflict among research goals. Describing classroom phenomena without intruding and changing its nature as it is observed, requires an unobtrusive, responsive research style. Describing relationships among variables with exactness and precision requires some control over the research setting.

We handled these conflicts through use of a research design that employed both quantitative and qualitative techniques. Data collection procedures emphasized non-reactive measures and systematic observation in addition to formal quantitative measurement procedures. The primary method of data collection was open-ended interviews, with guides that focused field staff on collecting data on the variables under study. Interviewers' notes were formalized through a technique known as the "Site Survey Method." Using the site survey, field staff translated their detailed observational and interview notes onto an extensive questionnaire (rather than writing a formal case study). The questionnaire contained both open-ended and closed-ended items that elicit data with respect to key variables under study. Additionally, the site survey instrument provided data that could be used to estimate inter-interviewer reliability.

Fieldwork Procedures

Once teachers, districts, and schools were selected and scheduled to participate in the study, most of the data collection occurred on-site. The primary method was semi-structured interviews that were translated onto the site survey. Interviews with district and school officials focused on district policy and support for microcomputer use in classrooms. Interviews with teachers provided most of the data directly relevant to uses of microcomputers in instruction. They were asked about their general instructional decisions and practices, uses of microcomputers for instruction, and the classroom context in which instruction occurred. They were also asked to make suggestions for improving teacher training and the quality of educational courseware.

Interviews were augmented with other methods of data collection. We observed how microcomputers were used instructionally in the given learning environment. We also noted the physical context of microcomputer use (i.e., the number, type, and location of available equipment) and examined the courseware used during the observation period.

In addition, through a parallel study funded by The Rand Corporation, we obtained biographical data from teachers through a self-administered questionnaire (Appendix A). This provided information on their educational and teaching background, and their experiences with and attitudes toward computers. Questionnaires were distributed to respondents prior to fieldwork and were returned by mail or retrieved during site visits. Questionnaires were returned by all the teachers in the sample (and by 91 percent of all teachers receiving them).

These interviews, observations, and instruments provided data on specific indicators of the larger conceptual variables of interest (see Figure 1.3 in the previous section). The overall data collection effort is summarized in Table 2.1, which identifies the conceptual variables, and specifies procedures used to collect data from participants. (Appendix A contains the instruments used to collect these data.)

Table 2.1

METHODS AND SOURCES OF DATA ON MICROCOMPUTER USE

Conceptual Variable	Method	Source of Data
District and School Context	Interview	District and School Administrators
Classroom Context	Interview; Observation	Teachers
Instructional Decisions and Practices	Interview; Observation	Teachers
Microcomputer Use	Interview; Observation	Teachers
Computer Knowledge	Interview; Questionnaire	Teachers
Subject-Matter Knowledge	Interview; Questionnaire	Teachers
Attitudes toward Computers	Questionnaire	Teachers

Fieldwork was conducted during the winter and spring of 1983. Field staff attended training prior to the beginning of fieldwork to become familiar with study issues, methods, and procedures; they also participated in a pilot study in two local districts.

Each interview was conducted by a single interviewer. The field staff interviewed teachers selected to participate, as well as someone knowledgeable about school and district policies, regarding microcomputer use. The school principal was usually interviewed regarding school policies; district-level respondents included assistant superintendents, curriculum coordinators, and, occasionally, designated computer coordinators. Given the unique role played by county education offices and state-supported Teacher Education and Computer (TEC) Centers in providing training and support, we occasionally interviewed one of their representatives to learn about a district's training and support policies. Interviews with respondents lasted approximately one hour. We also observed the teacher for at least an entire class period, typically 50 minutes in length.

At the conclusion of the fieldwork, field staff filled out a "Site Survey Instrument" which formalized field notes and observations. The quantitative data generated by this procedure was used in the analyses to be reported. To insure that data generated by each member of the field staff were comparable, we conducted reliability analyses on a sample of interviews. Unfortunately the reliability of the interviewers' ratings could not be estimated in the field because each interviewer met with a different set of teachers (for budgetary reasons). Thus, a small reliability study was conducted on 17 variables drawn from a sample of 15 teacher interviews.[2] The 15 interview field notes came from the three major interviewers, five interviews each. All four members of the field staff filled out a site survey instrument based on the field notes.

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[2] Actually, reliability was estimated within the framework of generalizability theory (Cronbach, Gleser, Nanda, and Rajaratnam, 1972; Shavelson and Webb, 1981). We assumed that unreliability may arise from systematic differences between mean ratings among interviewers since different teachers were interviewed by different interviewers, as well as from unidentified and unsystematic sources of variation. If $\sigma^2(T)$ represents the universe (true)-score variance for teachers, $\sigma^2(R)$ represents the constant bias of raters, and $\sigma^2(TR)$ represents the error due to particular raters associated with particular teachers and unsystematic variation, the reliability of a single rater was defined as:

We found that the reliability of a single rater's ratings was high, with a median value of 0.81 and a range of 0.22 to 1.00 over the 17 variables. Information on the reliability of specific variables is given as they are discussed in the following sections.

CHARACTERISTICS OF THE FIELDWORK SAMPLE

Our procedures for locating candidate teachers, districts, and schools produced a varied collection of computer-using educators and learning environments. The final sample consisted of 60 teachers, 25 districts, and 49 schools, based on initial contacts with 145 teachers nominated as "successful."[3] The 60 teachers, 31 of whom were female, fulfilled the minimal definition of using microcomputers as part of ongoing instruction in math, science, or both, and of making decisions about the form and content of the microcomputer-based learning activities.

Teachers in the final sample, based on information provided in their biographical questionnaire, exhibited considerable diversity in background. Their teaching experience ranged from 2 to 38 years with an average of 15.8 years. They also varied as to undergraduate major, and the percent of all undergraduate courses taken in the disciplines and education (see Table 2.2). Virtually all held positive attitudes toward computers.

Overall, teachers indicated that their students were about average in ability (mean=2.03 on a 3 point scale) but the ability composition of individual classrooms varied from low to high (standard deviation of 0.71). On average, classrooms were comprised of 38 percent minority, but this figure varied greatly from one classroom to another with a

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$$r(1) = \frac{\sigma^2(T)}{\sigma^2(T) + \sigma^2(R) + \sigma^2(TR)}.$$

[3] Of the 145 teachers contacted, 49 were using microcomputers for literacy or programming, or as a laboratory instructor, and not for classroom instruction; 24 reported only very limited use; 7 were unavailable for observation; 5 did not return the biographical questionnaire; and 60 participated.

standard deviation of 32.31. Indeed, the percent minority ranged from 0 to 98 percent with a mode of 0 and a median of 32.5 (see Table 2.2).

Districts and schools also proved to be considerably diverse in characteristics and policies. Of the 25 districts, 14 were unified school districts, 7 were elementary, and 4 were secondary. Students served in the districts ranged from 5 to roughly 90 percent minority, and their performance on statewide measures of reading and mathematics achievement covered the first to fifth quintiles (see Table 2.3).

The number of microcomputers available for instruction in the districts ranged from 10 to 98 with a mean of 59 and a standard deviation of 38. Districts differed greatly in the manner by which microcomputers were introduced into instruction; six were district

Table 2.2

CHARACTERISTICS OF TEACHERS AND THEIR CLASSROOMS

Variables	Mean	Median	Mode	Standard Deviation	Range
Classroom Composition					
Number of students	29.22	30.08	30.00	4.87	24
Percent minority	37.98	32.50	0.00	32.31	98
Percent male	53.67	50.22	50.00	10.14	63
Socioeconomic status [a]	2.92	2.93	3.00	1.48	4
Ability level [b]	2.10	2.12	2.00	1.44	3
Teacher Characteristics					
Years full-time teaching	15.80	15.60	17.00	7.62	36
Percent all undergraduate courses taken in:					
Science	23.55	18.50	20.00	20.07	54
Mathematics	15.67	10.36	10.00	13.02	52
Computer science	1.02	0.11	0.00	2.85	13
Social science	18.17	10.50	10.00	19.05	99
Humanities	21.12	16.00	10.00	18.57	70
Education	12.88	9.83	0.00	14.32	57
Attitude toward computers [c]	1.77	1.90	2.00	0.56	2

[a] Scale ranged from 1=low to 5=high.
[b] Scale ranged from 1=low to 3=high.
[c] Scale ranged from 0=disagree, 1=agree, 2=strongly agree.

initiated, 8 were "grass roots" or teacher initiated, and 11 were initiated cooperatively by administrators and teachers. Districts also provide various degrees of support, including financial and expert personnel, for microcomputers; 17 provided some support, while 8 provided none. Differences also existed in the extent to which decisions affecting computer use were shared among different levels of staff; five shared decisionmaking regarding equipment and 9 regarding courseware.

Likewise, schools differed in the number of microcomputers available and in their policies for encouraging and supporting them. Schools in the study had 12.23 microcomputers, on average, with a range from 1 to 55. Forty percent of the schools placed their microcomputers in labs while the remainder placed the computers in classrooms or in adjoining rooms. About half of the schools provided resources for instructional computer use. Commonly these resources were small budgets for hardware or courseware purchases (often under $500.00 annually).

Table 2.3

CHARACTERISTICS OF SCHOOL DISTRICTS

Variable	Mean	Standard Deviation	Range	Quintile	N
Reading Achievement					
Grade 3	274.76	39.07	205-331	3	21
Grade 6	269.67	33.80	214-335	3	21
Grade 12	65.86	4.84	56.6-75	2	18
Mathematics Achievement					
Grade 3	278.43	36.16	216-336	2	21
Grade 6	274.52	33.06	218-335	2	21
Grade 12	71.15	5.74	61.6-82.1	1	18
Percent AFDC					
Grade 3	15.11	12.24	0.4-38.0	-	21
Grade 6	14.17	11.43	0.1-36.0	-	21
Grade 12	9.39	9.43	0.1-33.9	-	18
Percent Minority	32.21	25.10	5.6-87.5	-	25

Approximately two-thirds of the schools provided incentives for computer use. Most often, the incentive was release time for teachers, usually to attend a workshop on microcomputers (43 percent of the schools). Less frequently used incentives were additional pay (13 percent), permission for teachers to take the microcomputer home to learn how to use it and develop instructional materials (15 percent), and school-wide recognition for microcomputer use (18 percent).

III. PATTERNS OF MICROCOMPUTER-BASED INSTRUCTION

This study sought to describe the ways in which teachers, nominated as "successful," use microcomputers for mathematics and science instruction. To this end, we had to enumerate the attributes of microcomputer-based instruction. These attributes would then serve as the initial basis for describing patterns of instructional uses. These patterns would be further described (and validated) on a set of additional pedagogical variables. In this section, then, we define attributes of instructional microcomputer use and measures of them. Next, we present the results of a cluster analysis that sorted the 60 teachers into four groups with each group representing a different pattern of instructional use. Finally, we report on other instructional practices associated with these different patterns.

DEFINITION OF INSTRUCTIONAL MICROCOMPUTER USE

This study depends importantly on establishing a working definition of the *attributes of instructional microcomputer use* so that they may be measured and used to distinguish empirically among patterns of mathematics and science instruction with microcomputers. This definition focuses on how teachers integrate computer activities into classroom instruction; it inevitably rests on an underlying conception of teaching. This conception guides the selection of the attributes of microcomputer-based instruction, including key decisions teachers must make about courseware selection and linking classroom activities with computer activities, as well as related instructional practices. It links classroom practices to outcomes and highlights the importance of feedback on computer-based activities.

A particularly useful framework for building the definition derives from theories of teaching that may be termed "teachers' decisionmaking" (e.g., Shavelson, 1973, 1976, 1983; Shavelson and Stern, 1981) or "clinical information processing" (Shulman and Elstein, 1975). This framework helps to define instructional computer use because it suggests specific teaching decisions that underlie microcomputer use and teaching tasks in which computers may play a role. The basic premise of the

tasks in which computers may play a role. The basic premise of the

decisionmaking approach is that instruction is an ongoing process under the active direction of teachers. Instruction is viewed as multifaceted, with goals, content, activities, and teaching methods orchestrated by teachers in order to provide a flow of activity toward hoped-for outcomes. Teachers' plans are a central focus of this conceptualization. In formulating and evaluating plans, teachers integrate information about students, the subject matter, and the classroom and school environment in order to reach judgments or decisions that guide instructional activities. Furthermore, teachers monitor ongoing activities. If activities are proceeding as planned, teachers concentrate on maintaining the flow of activity. If the activities are not going according to plan (i.e., some disruption occurs), they activate a routine for handling the problem. A final monitoring loop occurs when teachers evaluate the outcomes of instruction in order to improve planning. (For a detailed presentation of the underlying cognitive and pedagogical theory, see Shavelson, 1976, 1981, 1983; Shavelson and Stern, 1981).

To begin to define attributes of instructional computer use, we first assume that computer use fits within teachers' ongoing planning and decisionmaking processes. Next, we assume that teachers can make reasonable choices among alternative courseware for reaching one or some combination of educational goals, and among the modes of microcomputer-based instruction (e.g., drill and practice, simulation) given their knowledge of the subject matter, computers, and the characteristics of students in their class. We believe that "successful" microcomputer using teachers will make reasonable decisions about matching the computer and available courseware to the instructional goals, the structure of the subject matter, the nature of the students, and the context of instruction. Nevertheless, once the planning decisions have been made, the teacher must possess the interactive teaching skills needed to carry out the plan. Finally, teachers must monitor their ongoing instruction, take appropriate steps when warranted, and retrospectively evaluate their decision rules, choices of courseware, and so on in order to improve the match between computer activities and other facets of ongoing instructions. In such a case, then, the

decisionmaking conception predicts that student outcomes would be
decisionmaking conception predicts that student outcomes would be
maximized.

This conceptual framework implies that instructional computer use is inherent in teachers' planning and decisionmaking that is linked to the conduct and evaluation of instruction. In general, the framework suggests that the use of computers should be defined as the degree to which computer activities are integrated into teachers' planning processes, in the sense that computer activities should be related to other instructional activities and tasks. However, we need to expand this definition to allow for the pedagogical consequences of instructional computer use. Accordingly, we propose a general definition of instructional use that takes the elements of planning, computer uses, and pedagogical consequences into account, as follows:

> Instructional computer use involves the *appropriate integration* of *computer-based learning* activities with *teachers' instructional goals* and with the *ongoing curriculum*, which changes and improves on the basis of *feedback* that indicates whether desired outcomes are achieved.

Attributes of Instructional Microcomputer Use

This definition contains a number of conceptual elements--instructional goals, ongoing curriculum, computer-based learning activities, appropriate integration, and feedback (see Table 3.1). Each element in turn contains specific, measurable indicators that, together, constitute an operational definition of instructional microcomputer use. We describe these briefly below, indicating those variables on which data were collected.

Teachers' Instructional Goals. Teachers' goals for students are one important element of the definition. We focus on teachers' goals because our decisionmaking framework assumes that teachers' behavior is purposive--i.e., goal oriented. One must understand what objectives teachers seek to accomplish in order to later determine the importance of an instructional tool in meeting these goals.

Table 3.1

ELEMENTS OF SUCCESSFUL CLASSROOM COMPUTER USE

INSTRUCTIONAL GOALS

- (a) Achievement
  - 1. Mastery of basic skills/procedures
  - 2. Acquisition of subject-matter concepts
- (b) Motivation
- (c) Social

ONGOING CURRICULUM

- (a) Subject matter
  - 1. Content areas
  - 2. Major topics
- (b) Course materials
  - 1. Manipulable/Demonstrations
  - 2. Information sources (e.g., lectures; texts)

COMPUTER-BASED LEARNING ACTIVITIES

- (a) Modes of computer use
  - 1. Drill and practice
  - 2. Tutorial
  - 3. Simulation
  - 4. Microworlds
  - 5. Games
- (b) Grouping of students
- (c) Time allocation among students for computer use

APPROPRIATENESS OF INTEGRATION

- (a) Contribution of computer use for instructional goals
- (b) Coordination between the curriculum and computer use
- (c) Strategies for assigning students to computer activities

FEEDBACK

- (a) Evaluation of student progress
- (b) Use of CMI for management
- (c) Changes in computer-based activities

Teachers' goals may include outcomes that are academic, motivational, social (including behavior management), or some combination of these. Academic goals include acquisition of subject-matter concepts and mastery of basic skills. Motivational goals include such things as heightened student interest in the subject matter and positive attitudes toward class. Social goals may foster either behavior management or social cooperation and teamwork among students. Indeed, one of the most complex tasks faced by the teacher is that of balancing multiple goals within a lesson. Computers introduce an additional order of complexity into this balancing act.

To ascertain instructional computer use, we need first to determine the absolute and relative importance of these instructional goals to teachers. Interviews with each teacher identified, among other things, his or her goals for subject-matter instruction and the degree to which the microcomputer was used to help reach them. Specifically, the interviewer sought information about the extent to which microcomputers were used to help students master basic skills, acquire new conceptual knowledge, increase their motivation for subject-matter learning, and manage their behavior in the classroom. From this information, the interviewer rated the extent to which microcomputers helped reach these goals; the measures are defined in Table 3.2.

As discussed in the previous chapter, inter-interviewer reliability was estimated for a sample of variables derived from field interview notes based on interviews with 15 randomly selected teachers from the total sample of 60. The sample of variables included measures of the degree to which microcomputers helped the teacher reach his or her goal of basic skill mastery. The reliability estimated for a single interviewer interviewing a single teacher, as was done in the field, was 0.84.

Ongoing Curriculum. Teachers' goals are pursued in the context of a continuing classroom curriculum that is communicated through a number of instructional activities. We define the curriculum, as do teachers (Shavelson and Stern, 1981), to include: (1) *subject matter*--the major content areas and important concepts that are taught within each content area; and (2) *course materials*--the things that students observe and/or

Table 3.2

INDICATORS OF "SUCCESSFUL" MICROCOMPUTER USE

Variable	Source of Information	Definition
INSTRUCTIONAL GOALS		
Mastery goal	Teacher interview	The degree to which the teacher uses the computer to help reach basic skill goals (1=not at all ... 4=a great deal)
Cognitive goal	"	The degree to which the teacher uses the computer to help reach problem-solving goals (1 ...4)
Motivation goal	"	The degree to which the teacher uses the computer to help motivate students (1 ...4)
Management goal	"	The degree to which the teacher uses the computer to maintain an orderly classroom (1 ...4)
Microcomputer goal	"	Whether the teacher views student use of microcomputers as a goal in itself (0=no; 1=yes)
ONGOING CURRICULUM		
Instructional use	"	How extensively the teacher uses the computer for instruction (1=not at all ... 4=extremely)
Coordination	"	How well coordinated computer-based activities are with other instructional activities (1 ...4)
Perceived integration	"	Teacher's rating of the extent to which he/she has integrated computer activities with the regular curriculum (1 ...4)

Table 3.2

INDICATORS OF "SUCCESSFUL" MICROCOMPUTER USE
(continued)

Variable	Source of Information	Definition
Integration	"	Interviewer's rating of the teacher's integration (1 ...4)
Other subjects	"	Whether the teacher uses the microcomputer other than for instruction in math or science (0,1)
COMPUTER-BASED LEARNING ACTIVITIES		
Number of modes	Teacher interview	The number of different modes of instruction used on the computer (e.g., drill and practice, simulation, problem-solving, computation) (Total possible=6)
Group size	"	The number of students the teacher typically assigns to a microcomputer at one time (1, 2, or more)
Equal time	"	Whether or not equal computer time is allocated to students (0,1)
APPROPRIATENESS OF INTEGRATION		
Perceived success	"	Teacher's rating of the extent of success he/she has using microcomputers instructionally (1=not ... 4=very)
Success	"	Interviewer's rating of the teacher's success (1 ...4)
FEEDBACK		
Change use	"	Whether the teacher has modified instruction with computers based on feedback (0,1)

manipulate (e.g., laboratory equipment; exercises) as well as vehicles of course content such as textbooks and lectures.

These elements are important to note because they define the range of activities in which microcomputers can be potentially integrated. For this assessment, computer use was viewed in relation to teachers' planning decisions for coordinating computer use with the various instructional activities occurring in the class.

Based on interviews with teachers, interviewers rated the degree to which microcomputer activities were used ("Instructional Use"; reliability= 0.61, Table 3.2) and coordinated with other classroom activities (see Table 3.2, "Coordination"), the degree to which the content of microcomputer instruction was integrated with regular classroom subject-matter instruction ("Integration"; reliability=0.49), and whether the teachers used computer-based learning with any other subject matter (or class; "Other Use"). In addition, teachers were asked to indicate the degree to which they integrated microcomputers into the regular curriculum.

Computer-based Learning Activities. Another element of our definition relates directly to microcomputer-based learning technology. The decisionmaking perspective suggests that, during planning, teachers will make important distinctions among potential instructional uses.

One important distinction can be termed *mode of computer use*, and refers to the selections teachers make among the forms of available computer applications, such as drill and practice, tutorial, simulation, microworlds, and games (see Appendix C for details of these and other instructional modes). A second dimension relates to *grouping of students* for microcomputer use--how teachers assign students to computer activities. Teachers may have preferences for individual use, or they may view computer activities as something to be engaged in by pairs or groups of students. A final distinction relates to the *allocation of time* among students or groups of students for computer activities. Teachers may decide that computer activities should be allocated to students equally, or in proportion to some criterion such as need or ability.

From interviews and class observations, the interviewers determined the different instructional modes used by each teacher and the number of different modes served as a measure of the variety of courseware selections (Table 3.2). The reliability of interviewers' designations of drill and practice, tutorial, and simulation was 0.31, 0.85, and 0.82, respectively. (The low reliability associated with drill and practice was due to restricted range; most teachers used drill and practice.) In addition, information was collected on the number of students typically using a microcomputer at one time ("Group Size") and about whether students received equal time on the computer ("Equal Time").

Appropriateness of Integration. The various elements described above come together in considering the integration of computer use with instruction, and the appropriateness of the various forms of integration. Integration of computer-based learning activities (modes of use, grouping, time allocation) can occur with respect to *instructional goals* and the *curriculum*. For example, the fact that teachers have numerous instructional goals implies that the computer could be put to a variety of alternative uses; e.g., simulation programs for goals like heightening students' understanding of a process, or games for other goals like motivation. Students could be grouped or time allocations could be made in pursuit of certain other goals, such as fostering teamwork in problem solving or remediation of deficiencies in basic skills.

Coordination could also be made between computer-based learning activities and various elements of the curriculum (i.e., subject matter and course materials). Courseware can be selected, or mode of computer use assigned, to complement subject-matter content and existing course materials (e.g., textbooks or demonstrations). Grouping of students, and time allocation for various assignments, may also relate in some way to ongoing instructional activities.

Thus, each of the previous elements can be examined for the *breadth* of the match that is made between them. However, underlying the integration must be some notion of the appropriateness or pedagogical value of the strategies teachers follow in assigning students to computer use. The achievement of simple goals, such as keeping children on the computer and out of trouble, should not be considered appropriate instructional computer use. Likewise, the *mix* of goals is also important. For example, low ability students might continually be segregated at the computer from their peers in order to receive drill and practice. While this might optimize achievement outcomes, it changes the classroom context by isolating certain groups of students from others.

In a sense, appropriateness of integration implies a well orchestrated classroom (or laboratory) in which the microcomputer is an important instrument. We therefore interviewed teachers to determine their perceived success in integrating the microcomputer into their instruction ("Perceived Success"; reliability=0.71), and to enable the interviewer to rate overall success ("Success").

Feedback. The decision model of teaching indicates that teachers' evaluation and, if necessary, modification of instruction relative to their goals are an important part of teaching. To evaluate instruction, the teacher must obtain *feedback* about the consequences of instruction for their (a) students (e.g., student participation, time on task, expressed attitudes, subject-matter mastery), (b) teaching routines (e.g., links between computer activities and other instructionally related activities), and (c) planning decisions (e.g., selection of courseware, grouping of students).

Another element, then, is the evolution of computer use that occurs in response to feedback regarding the teacher's perception of its success. We have identified two indicators of the use of feedback. The first is whether teachers monitor microcomputer activities through formal or informal evaluation of students' time on task or progress through the subject matter. Because the computer provides an excellent way of tracking individual student progress for the purpose of instructional decisionmaking, a second indicator is whether the computer (or particular software) is used to provide teachers with feedback on individual student's progress on instructional tasks. Both sources of information may lead to changes in computer use through decisions like rejecting certain courseware, decreasing (or increasing) the time a student spends with the computer, and so on. Interviews, then, sought information about teachers' formal and informal evaluation of students, and about use of computer management systems, to determine whether teachers modified their computer-based instruction ("Change Use"; Table 3.2).

PATTERNS OF MICROCOMPUTER USE

The operational definition of instructional microcomputer use identifies a number of dimensions of microcomputer use, but it is not yet clear how independent they may be of each other. If these dimensions are closely related to one another in practice, it would be possible to identify a continuum of practices and to order teachers along that continuum. That is, if those teachers who establish multiple goals for microcomputer use are also those who integrate and coordinate the microcomputer with the curriculum and classroom activities, use multiple modes of instruction as appropriate, and modify their instructional practice based on feedback, distinctions among conceptual dimensions would not be as important. A single dimension, then, might be used to describe teachers' microcomputer-based instruction.

In contrast, some teachers might integrate and coordinate microcomputer instruction to help students master basic skills, using drill and practice primarily, while other teachers might use the microcomputer for enrichment, using a variety of instructional modes with only loose coordination of computer-based activities with other classroom activities. In this case, the conceptual distinctions among the dimensions would be important, and teachers' microcomputer-based instruction could not be described simply on a single dimension. Rather, patterns of use, some possibly more valued than others, would describe differences among teachers.

In order to examine the underlying relationships among the measures of the attributes of microcomputer use defined in Table 3.2, correlations were calculated among them. The results supported a multidimensional rather than a unidimensional interpretation of successful instructional microcomputer use. Excluding the summary judgments (Integration and Perceived Integration, and Success and Perceived Success), all but two of the 66 possible correlations among the 12 variables in Table 3.2 were less than 0.30 in absolute value.

Coordination and Instructional Use correlated 0.56 and Coordination and Other Use correlated 0.33 (see Tables B-3 and B-4 in Appendix B).

Recognizing that "successful" teachers used microcomputer-based instruction in more than one way, we sought a typology with which to describe *patterns* of instructional uses.[1] Methodologically, we used cluster analysis, a statistical procedure (e.g., Hartigan, 1975; for educational applications, see Shavelson, 1979), to group together teachers with similar repertoires of use and to distinguish them as clearly as possible from teachers in other groups. (For methodological details of the cluster analysis and of the interpretations of the patterns of microcomputer-based instruction employed by teachers in the clusters, see Appendix B.)

Four clusters emerged from the analysis. Cluster 1 (n=18), called "orchestration," represented the widest variety of instructional applications closely linked to regular curricular activities. Cluster 2 (n=23), termed "enrichment," capitalized on available courseware to familiarize students with microcomputers and, as a consequence, integrated computer activities with subject matter and other classroom activities least of any cluster. Cluster 3 (n=14), dubbed "adjunct instruction," used the computer to selectively augment lessons in mathematics and science, with what courseware was available in these subjects. Cluster 4 (n=5), labeled "drill and practice," stressed this instructional mode and basic-skill objective, and tied computer-based instruction closely to the curriculum and classroom activities. Below, the four clusters are described in detail.

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[1] We fully recognize the potential pitfall of creating typologies, especially in describing a rapidly evolving phenomenon such as microcomputer-based instruction. We believe that by creating a typology the benefit of capturing variation in instructional patterns among "successful" teachers outweighs the potential harm of creating an image of microcomputer-based instruction that would stifle its evolution. The typology serves as a short-term snapshot that may or may not prove useful to teacher educators and software developers. All should keep in mind that the phenomenon is changing.

Orchestration Cluster

Cluster 1 was termed "orchestration" because teachers in this cluster stressed both cognitive and basic-skills goals, as well as computer use as a goal in and of itself; used a variety of instructional modes to meet these goals (e.g., drill and practice, tutorial, simulation, microworld, game); integrated the content of computer-based instruction with the ongoing curriculum, and coordinated computer activities with other instructional activities; changed their uses based on feedback from students; and, not surprisingly, were evaluated as most successful in their use of microcomputer-based instruction during field visits by our staff, and by themselves (see Figure 3.1; for descriptive statistics and statistical tests, see Appendix B). Of the four clusters, the orchestration cluster represented the fullest instructional use of microcomputers by virtue of using microcomputers in ways set forth in our definition above.

Ms. Jones is representative of teachers in the orchestration cluster. She was introduced to microcomputers about seven years ago, when her husband, a scientist, bought a PET to use at home. Four years ago she began a district pilot project on classroom uses of computers with her own computer. Now she has three PETs in her classroom and more microcomputers in a laboratory.

Ms. Jones teaches 30 mixed-ability, third and fourth graders of low to middle socioeconomic background; half are boys and one-fourth are minorities. Microcomputer-based instruction is *integrated* with the major topics covered in mathematics: addition, subtraction, two-place multiplication, division, fractions, and measurement. She *coordinates* computer activities with the textbook, dittoed worksheets, and other instructional aids (e.g., the clock is used to teach "time-telling"). She stresses as *instructional goals* for mathematics both mastery of basic skills and acquisition of higher cognitive skills (e.g., analogical relationships and logical thinking); positive affect toward mathematics is a third, but less-stressed goal. She reports that the computer helps her meet each of the instructional goals; in particular, *drill and practice* programs provide immediate feedback in a non-threatening atmosphere. She believes that the microcomputer gives the

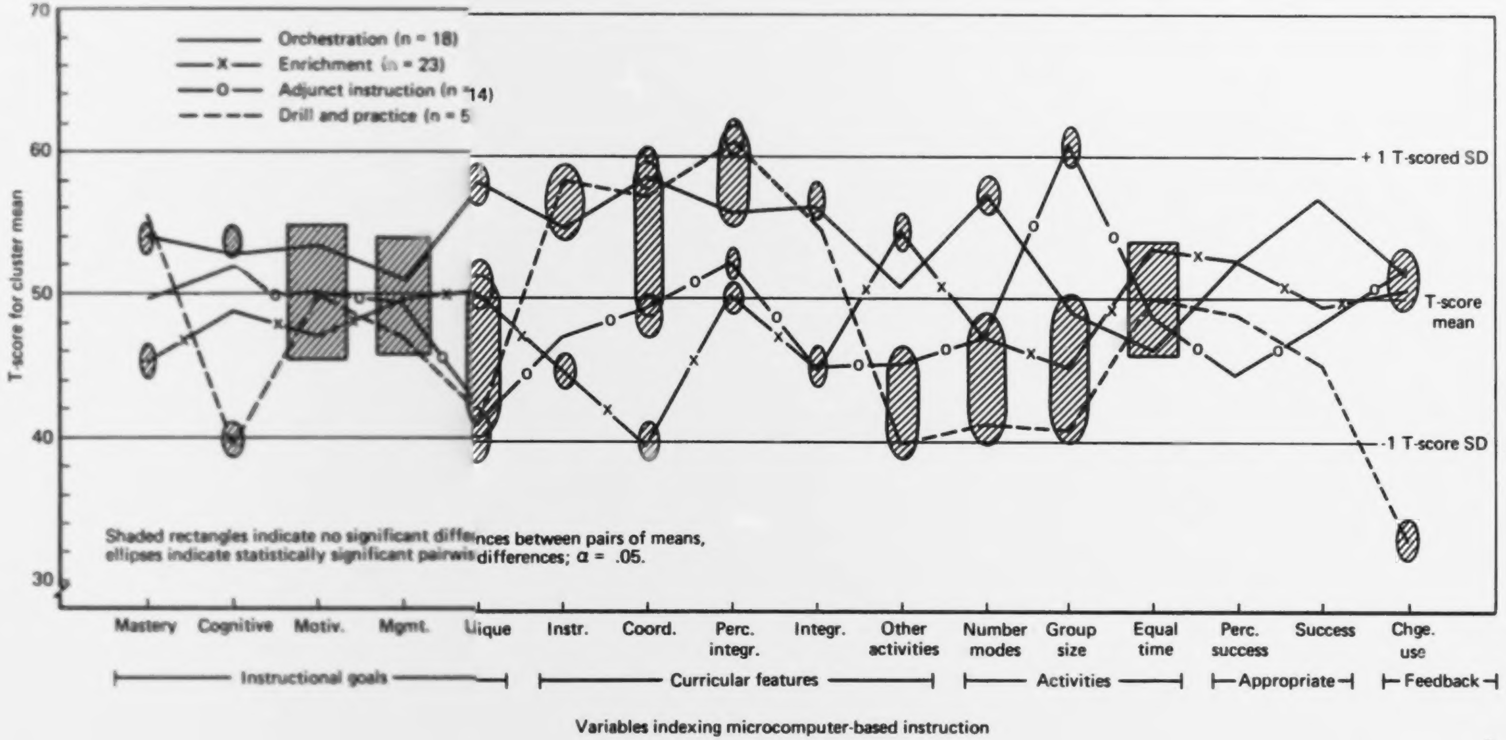

Fig. 3.1 -- Profile of similarities and differences among patterns (clusters) of microcomputer-based instruction

students a feeling of control, i.e., that the teacher does not control everything. Finally, the computer motivates the students and gives her time to do other things.

Ms. Jones uses the microcomputer as a *teaching aid* for about 20 minutes per week. Her *students use the microcomputer daily*, in the classroom and in the lab, for an average of about 90 minutes of computer-based instruction per week. *Drill and practice, tutorials*, and *simulations* are used most frequently, but *microworlds* (e.g., Kidstuff), and *games* are also used. She also teaches some programming in BASIC. For mathematics instruction, she has three ability *groups*, one assigned to each of the three computers in her classroom. Students usually work *individually* on programs matched to their achievement level, but also work in small groups when courseware requires it.

The computer proved to be more versatile as a teaching aid than she first imagined. As a result, she has *changed* the way she uses her teaching time. For example, she relies on the computer to do remedial *drill and practice* for students who need it, and uses the time to teach more skills. The microcomputer is also used for student *recordkeeping* and *testing*.

In our observation of the classroom, some students worked on the computer with remedial drill and practice programs in mathematics while others used the word processor to write stories. (Ms. Jones uses the computer for *other subjects* besides mathematics; the "storywriters" were working on an English assignment.) The atmosphere was chaotic--to be expected when 30 eight- and nine-year-olds occupy one-third of a "pod" in an open-plan school. In spite of the chaos, there was a feeling of order in the activity, and students were thoroughly engaged in either their seatwork or computer activities.

In addition to teaching, Ms. Jones serves as the computer resource person at her school and district, and she teaches many of the staff-development courses. In her "spare" time she reviews courseware, writes or modifies courseware, and writes articles about computers. In the summer, she turns her kitchen into a computer learning laboratory for children six to thirteen years of age and their teachers.

Enrichment Cluster

Teachers in the enrichment cluster were least inclined to integrate computer-based instruction with the ongoing curriculum, or to coordinate this activity with other classroom activities, or to use the microcomputer to help students master basic skills. Thus, they tended to use microcomputers less for instruction than teachers in clusters 1 and 4. However, teachers in this cluster are most likely to use the microcomputer in instruction in subjects other than mathematics or science, or for word-processing. And more teachers in this cluster than in clusters 3 and 4 encouraged microcomputer use in its own right. This suggests that their computer use was somewhat ad hoc and served as an end in itself more than as an instructional means. Although these teachers, on average, viewed themselves as successful in microcomputer-based instruction as teachers in the orchestration cluster, staff field evaluations were less positive (Fig. 3.1).

Mr. Higgins is representative of the teachers in this cluster. He became involved with microcomputers through a combination of initiative and strong support from his principal, Mrs. Castillo. He took his district's elective staff-development workshops, and attended some classes at Radio Shack on his own. He requested a microcomputer for his class, and Mrs. Castillo acquired a TRS-80 with the help of the district math curriculum coordinator, Mr. Blum. Mr. Blum is also strongly supportive of microcomputer use in the district schools, but has few resources to provide. He purchased a handful of TRS-80s for the district with Chapter 1 funds, and uses a limited amount of administrative funds for occasional purchases of courseware. These are in turn passed along to teachers such as Mr. Higgins.

Consequently, Mr. Higgins currently has a limited amount of courseware available for his class of fifth and six graders that he describes as low in ability and in socioeconomic background, and we observed was composed of nearly 90 percent minority students. His philosophy of microcomputer instruction is to use the courseware to give each student the *opportunity* to spend some time with the microcomputer. He has established a sequence in which students progress through *basic-skills* programs in math and spelling providing needed drill and practice, followed by programs that enhance dictionary and logic skills to enhance their *reasoning ability*. Once students demonstrate proficiency in these lessons, they have a "free choice" period; *games* are among the options available.

Mr. Higgins posts a daily schedule for students' computer use on the blackboard. Each student spends ten minutes a day on the microcomputer--50 minutes a week. Luis, a student aide, keeps track of the schedule, supervises the operation of the machine, and makes sure that each student has the appropriate courseware. This involves updating the spelling program with the students' words for the week and placing the students at the correct level of the math sequence. Thus, although all students use the same courseware, the lesson content is individualized according to the student's ability. Nevertheless, the vast majority of programs are *drill and practice*.

These computer activities occur independently of concurrent classroom activities, as is characteristic of elementary classrooms. During the period in which we observed the class, some students read a history lesson and engaged in seatwork; others participated in a reading circle with the teacher. Mr. Higgins admits that the degree of *coordination* between microcomputer activities and other class activities is minimal, and that high quality courseware coverage of topics in mathematics and language arts is limited. He is satisfied, however, to note that the microcomputer is occupied by a student nearly all day and that the students enjoy the activity. He feels that as he gains more experience, he might be able to find some additional courseware to round out his instructional program.

Adjunct-Instruction Cluster

Teachers in cluster 3 were distinguished by their grouping decisions--they provided computer-based instruction to students in groups of two or more. Moreover, they confined microcomputer use to mathematics or science subjects, emphasizing *cognitive goals*, in a catch-as-catch-can manner that was not as closely integrated with the ongoing curriculum as was common among teachers in clusters 1 and 4. Unlike teachers in cluster 2 who try to use the microcomputer to provide a wide range, even if a somewhat limited amount, of instruction, the approach of the cluster 3 teachers appears to be to selectively augment certain lessons, and not to view microcomputer use as a goal in itself.

Ms. Fast is representative of the teachers in the adjunct-instruction cluster. She has taught with computers in her classes for almost four years, after being introduced to them by another teacher who had two terminals connected to a mainframe computer. She has taken training courses in educational technology offered through the district, as well as courses on her own, at a local state university. Regarded now as one of the two computer experts at the school, she actively promotes the use of computers in instruction. She feels that the pace of microcomputer implementation and training is much too slow, that more extensive training programs for teachers are needed, and that the training should place less stress on programming.

We observed Ms. Fast's 10th grade biology class of 30 students, about half of whom were female, and about 55 percent of whom were minorities, comparable to the school's ratio according to her. The students came from low to upper-middle income families, and most were of average to high ability.

Ms. Fast uses microcomputers to help attain the *goal* of higher-level *cognitive skills*, such as problem solving and reasoning. She also considers it important to use microcomputers to help give her students a feel for science as a process applicable to real-world situations, and to *motivate* scientific thinking skills in the students. She does *not emphasize basic skills* (possibly because her class does not require it), and does *not include class management* as one of her major goals for the class. Finally, she uses the computer to reinforce vocabulary and concepts for weaker students.

To help achieve her goals, she uses computer *simulations* in her classes. Students will read and discuss a topic (e.g., laws of population genetics) in class. Then they will explore the variables and relationships by using a simulation program. These simulations thus reinforce the understanding from the reading and discussion. Her students work at the computer in pairs, with a lab partner they select at the start of the year. Having *students work together* allows them to interact with each other as well as with the program, thereby helping reinforce the view of science as process. The strategy also helps alleviate the problem of access to the computer; each student uses the computer only about 3 times in the semester, for about 10 minutes each time.

When possible, students will be working on the *same content* at the computer and in class; however, this is not always possible for reasons of both hardware and software availability. Ms. Fast did *not emphasize* the *integration* of computer materials with other aspects of the course because she felt that too little courseware of sufficiently high quality was available to make this possible.

Drill and Practice Cluster

The number of teachers in cluster 4 was small (roughly 8 percent of the sample), but the teachers were very homogeneous in their use of microcomputer-based instruction. Each used *drill and practice* extensively and almost exclusively to achieve mastery of *basic skills* in mathematics or science (Fig. 3.1 and Table 3.4 below). Microcomputer-based instruction was *not used for* the acquisition of higher-order, *conceptual skills*, nor were microcomputers used to develop skills in using information technology. Computer-based instruction was delivered to students individually, was closely *integrated* with the ongoing curriculum, and was *closely coordinated* with other classroom activities. These teachers had *not changed* their *computer use since implementing it.*

Ms. Greg is representative of the five teachers in this cluster. About five years ago she was hired by her district as a mathematics-resource teacher and charged with raising the test scores of seventh and eighth graders, half males and three-fifths minorities, all of whom are low in ability and SES. She responded by developing an entire mathematics curriculum from whole numbers to geometry with the help of volunteers, acquiring a laboratory full of microcomputers with Title I funds, and *linking drill-and-practice* courseware written by an unemployed programmer *to the new curriculum*. Moreover, she accomplished all this without formal training in instructional microcomputer use; indeed, she pioneeered such use in other districts.

Her classes, averaging about 32 students each, are divided into four groups. She tutors students in one of these groups while students in the other groups are tutored by the three aides supported by Chapter I funds. Every fourth day, students are sent across the hall to a laboratory where a lab coordinator oversees their 50 minutes of drill and practice on mathematics problems *linked directly* to the *curricular strand* they are studying in class.

Ms. Greg's major instructional *goal*, in broad terms, is student *mastery* of *basic skills*. More specifically, she found that her students needed a great deal of practice in mathematics computation if they were to raise their test scores. Given the importance of practice in computation, she *uses only drill and practice* courseware in the microcomputer-based instruction. Hence, the microcomputer is a major partner in helping Ms. Greg substantially improve her students' mathematical skills.

Observations of students in the laboratory confirmed what Ms. Greg had told us about her instructional goals and plans. Students *worked individually* on a network of microcomputers, receiving drill and practice on topics ranging from addition to algebra depending on the student's curricular strand. The *courseware tracked* each student's *performance* and required the student to satisfactorily complete one strand before moving to the next. The lab coordinator moved from one student to the next, providing instructional help when asked. Without exception, the students were "glued" to the computers by interest; our presence went unnoticed after the first minute or so.

INSTRUCTIONAL DECISIONS AND PRACTICES

A wide variety of additional instructional decisions and practices are associated with instructional use of microcomputers. For example, decisions must be made and procedures implemented regarding the particular courseware to be used, the number and mix of students working with the microcomputers, the amount of time allocated to microcomputer-based instruction, and the behavioral rules established for using the microcomputer. According to our conceptual framework, variations in teachers' instructional decisions and practices regarding the attributes of successful microcomputer use (e.g., relative emphasis on different goals, number of instructional modes, coordination of activities) are expected to lead to differences in other decisions and practices regarding, for example, allocation of computer time, use of different instructional modes, and assignment of students to microcomputer instruction. If additional differences are found, they would help round out our understanding of alternative patterns of instructional use and provide valuable information for teacher education in microcomputer use.

To this end, we asked teachers about additional decisions and practices regarding microcomputer use, including their: (a) allocation of time for microcomputer use; (b) use of different instructional modes on the microcomputer; (c) rules for using the microcomputers; (d) strategies for grouping students; and (e) use of adult and student aides. In addition, we asked about the teacher's participation in courseware selection. Measures of their instructional decisions and practices are defined in Table 3.3.

Time Allocation

Teachers were asked to estimate how many minutes per week they used the microcomputer as an aid in their own instruction. They reported, on average, about 12-1/2 minutes; differences among clusters, however, were not statistically significant.

Teachers were also asked to estimate the number of minutes per week, on average, students received instruction on the computer (reliability=0.91). Although there may be some error in these time estimates, there is no reason to believe that teachers in one cluster would systematically overestimate or underestimate student time relative to the other clusters. Hence, relative differences in time estimates among clusters are of interest. We interpret the data in Table 3.4 as demonstrating considerable differences *within clusters* in teachers' allocation of time. The availability of microcomputers and courseware may drive time-allocation policies among teachers within a cluster. The differences among cluster means, however, were not statistically significant, even after appropriate transformation of the time-allocation data, taking into account the fact that as the means increased, so did the standard deviations.

Table 3.3

DEFINITION OF INSTRUCTIONAL USE VARIABLES

Variable	Primary Source of Information	Definition
TIME ALLOCATION AND ATTENTION		
Aid	Teacher interview	Number of minutes per week the teacher used a computer as an instructional aid in the classroom
Student time	"	Number of minutes per week the student spends using a computer
Student attention	Observation	Degree to which students are paying attention to computer-based instruction (1=not at all ... 4=completely)
MODES OF USE		
Drill	Teacher interview	The extent to which the computer is used by students for drill and practice (1=not at all ... 4=extensively)
Tutorial	"	The extent to which the computer is used by students for tutorial instruction (1 ... 4)
Simulation	"	The extent to which the computer is used by students for simulations (1 ... 4)
Microworld	"	The extent to which the computer is used by students to create a microworld such as LOGO does (1 ... 4)
Game	"	The extent to which the computer is used by students to play instructional or motivational games (1 ... 4)

Table 3.3

DEFINITION OF INSTRUCTIONAL USE VARIABLES
(continued)

Variable	Primary Source of Information	Definition
RULES FOR MICROCOMPUTER USE		
Game rule	Teacher interview	Whether the teacher has a rule regarding games while working on the computer (0=no, 1=yes)
Talking rule	"	Whether the teacher has a rule regarding talking while working on the computer (0=no, 1=yes)
Operation rule	"	Whether the teacher has a rule regarding operation of the computer while working on the computer (0=no, 1=yes)
Access rule	"	Whether the teacher has a rule regarding access to the computer while working on the computer (0=no, 1=yes)
Time rule	"	Whether the teacher has a rule regarding the amount of time a student spends while working on the computer (0=no, 1=yes)
STRATEGIES FOR ASSIGNING STUDENTS TO MICROCOMPUTER		
Mode-match	"	Whether students are matched with a particular mode of instruction (0=no, 1=yes)
Content-match	"	Whether students are matched with content topics and/or difficulty (0,1)
Ability	"	Whether students are grouped for computer use according to subject-matter content (0,1)

Table 3.3

DEFINITION OF INSTRUCTIONAL USE VARIABLES
(continued)

Variable	Primary Source of Information	Definition
Computer-knowledge	"	Whether students are grouped for computer use according to their ability to use the computer (0,1)
Other grouping strategy	"	Whether some other strategy was used for grouping students (0,1)
COURSEWARE ACQUISITION		
Participation in courseware decisions	"	Whether the teacher participates in school and/or district courseware (0,1)
District courseware	"	Whether the teacher uses courseware acquired by the school and/or district (0,1)
Teacher courseware	"	Whether the teacher acquires courseware on own initiative (0,1)
Write courseware	"	Whether the teacher writes his or her own courseware (0,1)

Table 3.4

TEACHERS' INSTRUCTIONAL DECISIONS AND PRACTICES
[Means and (Standard Deviations)]

Variable	Cluster [a] 1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	All (n=60)	Statistically Significant Contrasts [b]
TIME ALLOCATION AND ATTENTION						
Aid	16.77 (23.84) (n=13)	12.17 (20.91) (n=12)	11.71 (21.92) (n=7)	3.00 (6.71)	12.46 (20.67) (n=37)	ns
Student time	52.64 (72.02) (n=17)	63.95 (79.71) (n=22)	26.86 (24.31)	56.60 (32.68)	51.05 (64.95) (n=50)	ns
Student attention	3.75 (0.45) (n=16)	3.52 (0.51) (n=21)	3.33 (0.49) (n=12)	3.67 (0.58) (n=3)	3.56 (0.50) (n=52)	ns
MODES OF USE						
Drill and practice	0.72 (0.46)	0.78 (0.42)	0.86 (0.36)	1.00 (0.00)	0.80 (0.40)	ns
Tutorial	0.72 (0.46)	0.30 (0.47)	0.36 (0.50)	0.20 (0.45)	0.43 (0.50)	1>2
Simulation	0.83 (0.38)	0.48 (0.51)	0.57 (0.51)	0.00 (0.00)	0.57 (0.50)	1>4
Microworld	0.28 (0.46)	0.04 (0.21)	0.00 (0.00)	0.00 (0.00)	0.10 (0.30)	1>3
Games	0.50 (0.51)	0.52 (0.51)	0.21 (0.43)	0.60 (0.55)	0.45 (0.50)	ns
RULES FOR MICROCOMPUTER USE						
Game rule	0.17 (0.38)	0.22 (0.42)	0.29 (0.47)	0.80 (0.45)	0.27 (0.45)	4>1,2
Talking rule	0.39 (0.50)	0.17 (0.39)	0.57 (0.51)	0.40 (0.55)	0.35 (0.48)	ns

Table 3.4

TEACHERS' INSTRUCTIONAL DECISIONS AND PRACTICES
[Means and (Standard Deviations)]
(continued)

Variable	Cluster [a]				All	Statistically Significant Contrasts [b]
	1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	(n=60)	
Operation rule	0.33 (0.49)	0.61 (0.50)	0.43 (0.51)	0.20 (0.45)	0.45 (0.50)	ns
Access rule	0.11 (0.32)	0.17 (0.39)	0.29 (0.47)	0.20 (0.45)	0.18 (0.39)	ns
Time rule	0.22 (0.43)	0.17 (0.39)	0.50 (0.52)	0.20 (0.45)	0.27 (0.45)	ns
STRATEGIES FOR ASSIGNING STUDENTS TO MICROCOMPUTERS						
Mode match	0.39 (0.50)	0.35 (0.49)	0.29 (0.47)	0.20 (0.45)	0.33 (0.49)	ns
Content-match	0.72 (0.46)	0.74 (0.45)	0.43 (0.51)	0.80 (0.45)	0.67 (0.48)	ns
Ability	0.17 (0.38)	0.09 (0.29)	0.14 (0.36)	0.00 (0.00)	0.12 (0.32)	ns
Computer-knowledge	0.00 (0.00)	0.04 (0.21)	0.07 (0.27)	0.00 (0.00)	0.03 (0.18)	ns
Other	0.56 (0.51)	0.30 (0.47)	0.79 (0.43)	0.00 (0.00)	0.47 (0.50)	1>2
COURSEWARE ACQUISITION						
Participates in decisions	0.88 (0.33) (n=17)	0.64 (0.49) (n=22)	0.64 (0.50)	0.50 (0.58) (n=4)	0.67 (0.48) (n=57)	ns
District/ school	1.00 (0.00) (n=17)	0.84 (0.37) (n=19)	0.86 (0.36)	0.60 (0.55)	0.87 (0.34) (n=55)	ns

Table 3.4

TEACHERS' INSTRUCTIONAL DECISIONS AND PRACTICES
[Means and (Standard Deviations)]
(continued)

Variable	Cluster [a]					
	1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	All (n=60)	Statistically Significant Contrasts [b]
Teacher	0.87 (0.35) (n=15)	0.65 (0.49) (n=12)	0.58 (0.51) (n=12)	0.25 (0.50) (n=4)	0.67 (0.47) (n=51)	ns
Write	0.33 (0.50) (n=9)	0.25 (0.45) (n=16)	0.33 (0.49) (n=12)	0.25 (0.50) (n=4)	0.29 (0.46) (n=41)	ns

[a] Cluster size is indicated by variable only when missing data are encountered.

[b] Level of significance, based on one-way analysis of variance, was $\alpha=.05$. Pairwise comparisons are based on Tukey's HSD test with unequal sample sizes ($\alpha=.05$); numbers refer to cluster numbers. Only two pairs of variables were significantly correlated: access and time ($r=0.69$); participates and teacher ($r=0.81$; see Table B-5 in Appendix B).

Finally, we rated the extent to which students attended to computer activities during our observations. However, there are obvious problems with this measure. First, accurate measures of attention are difficult to achieve from observation (Shavelson, 1976). What may appear as attentive behavior might well be intense thought about some event totally independent of the computer. Second, one hour of observation may not be sufficiently representative to portray typical levels of attention. These problems aside, data in Table 3.4 indicate student attention was uniformly high regardless of the pattern of microcomputer-based instruction.

Modes of Instructional Use

From interviews with the teachers, interviewers determined whether the teachers used computer programs characterized by drill and practice (reliability=0.85), simulation (reliability=0.82), tutorials, microworld, or games. (For detailed descriptions of these instructional modes, see Appendix A.) Teachers labeled as "Orchestrators" (cluster 1) were distinguished by their use of multiple instructional modes. The data in Table 3.4 indicate that those differences lay in the use of tutorials, simulations, and microworlds. Specifically, teachers in cluster 1 differed statistically from those in cluster 2 in their use of tutorials, from teachers in cluster 4 in their use of simulations, and from cluster 3 in their use of microworlds.

The fact that roughly three-fourths or more of the teachers in each cluster used drill and practice is significant, for at least two reasons. First, it reflects the fact that this type of courseware is most readily available. Second, it indicates that, although the clusters represent distinct patterns of use, none systematically exludes this mode of instruction. Recommendations to avoid drill-and-practice were not supported by our data. Rather, the issue and ensuing recommendations should focus on a balance in instructional modes, perhaps matching mode with instructional goal (skills versus concepts), subject-matter content, and student needs. Wholesale use of drill-and-practice is not supported either if schools seek to implement instruction in patterns other than that of the drill and practice cluster.

Rules for Microcomputer Use

Teachers were asked what rules, if any, had evolved for students to follow in their use of microcomputers. Past studies of microcomputer use (e.g., Sheingold, 1981) indicated that some teachers had developed such rules in order to achieve equitable time allocations for computer use. Our data confirmed this. Roughly a third or more of the teachers in each cluster had rules governing operation of microcomputers and talking at the computer; only about 20 percent had a rule governing time spent at the computer. In contrast, the clusters could be differentiated systematically by their rules for the use of games on the microcomputer. Four of the five teachers in the drill and practice cluster had a rule governing the use of games, whereas only about one in four teachers in the other clusters had such rules.

Strategies for Assigning Students to Microcomputers

Microcomputer-based instruction is most often conceived as individualized instruction with one student at the computer proceeding at his or her own pace. This, however, is too narrow a conception. Teachers might group students to jointly solve a problem using a simulation or a data-analysis program. Alternatively, grouping might be necessitated by a shortage of microcomputers.

If students are grouped, the decisionmaking framework leads us to inquire into teachers' assignment policies. Assignments might be made by matching instructional modes to student subject-matter or computer knowledge, or to the content and difficulty of the curriculum topics.

We asked teachers about their strategies for assigning computer activities and for grouping students. In general, we found, not unexpectedly, that roughly three-fourths of the teachers assigned students to microcomputers by matching of the content topics and difficulty to student needs (cf. Shavelson and Stern, 1981). Roughly half the teachers employed a more or less opportunistic strategy, taking advantage of courseware availability to provide opportunities for microcomputer use ("other" in Table 3.4). This strategy characterized teachers in the orchestration and adjunct-instruction clusters, less so those in enrichment, and was not characteristic of the drill and practice cluster. Other assignment policies were employed only by a small number of teachers and were not related to cluster membership.

Participation in Courseware Acquisition

Teachers' instructional use of microcomputers is driven in large part by the availability of courseware. Little is currently known about how teachers acquire the courseware. Courseware acquisition is particularly important judging by teachers' commonly voiced complaint that most courseware is poor in quality. For this reason, we asked teachers whether they participated in acquisition decisions and who supplied their courseware. The pertinent data are presented in Table 3.4.

Two-thirds of the teachers reported participating in courseware-selection decisions. Courseware is supplied both by the district/school *and* by the teacher. While two-thirds of the teachers acquired courseware, less than one-third reported authoring their own. These findings were consistent over the four different clusters of teachers.

CONCLUSIONS

Three conclusions emerge from this search for and description of teachers characterized as "successful" in their use of microcomputer-based mathematics and science instruction. The first conclusion is that, even in California, a state touted for high technology and enlightened policies regarding microcomputer-based instruction, "successful" teachers were extremely hard to find in the fall of 1982 and winter of 1983. These teachers were a scarce breed, despite the rhetoric of politicians, bureaucrats, computer companies, and educators. The search was complicated even further by the phenomena of the vanishing computer-using teacher (see Section II): teachers extremely successful in educational applications of microcomputers disappeared from their classes to become "computer coordinators" in their districts or software developers in the burgeoning information technology industry.

Policies for retaining these talented teachers in the classroom need to be explored. For example, current teacher salaries cannot compete with administrative and private sector salaries. Merit pay schemes for increasing salaries might improve salary leverage, although they may not if they are small or unpredictable from year to year. Equally, if not more important, is the improvement of working conditions. Such improvement might well begin by decreasing attempts to control teaching activities and increasing professional decisionmaking among these talented teachers. One way of improving working conditions and, perhaps, avoiding the vanishing computer-using-teacher phenomenon is to provide these teachers with increased responsibliity for hardware and courseware acquisition, and for training their peers. This would, of course, have to be legitimized by adequate budgets and control over them, release time to carry out these added functions, and some sort of valued incentive in recognition of their special expertise. For example, positions for "computer buffs" might well be built into career ladders or pay scales. If the conditions of teaching are not improved for these successful computer-using teachers, creative applications of microcomputer-based instruction may not achieve their potential, and many children will not experience and benefit fully from the capability of the new technology.

The second conclusion is that microcomputer-based instruction carried out by teachers who were dubbed "successful" by their peers, other educators, and administrators is not monolithic. These teachers varied greatly in: (a) their goals for microcomputer-based instruction (e.g., emphasis on mastery of basic skills, on acquisition of conceptual reasoning, or both); (b) the degree to which they used microcomputers instructionally, integrated computer-based instruction with the ongoing classroom curriculum, and coordinated computer activities with other instructional activities; and (c) the extent to which they varied the modes of microcomputer-based instruction, ranging from almost solely drill and practice to the orchestration of multiple modes including drill and practice, tutorials, simulations, microworlds, and games.

These differences in the microcomputer-based instruction of "successful" teachers were systematic and were captured by a statistical grouping of teachers into four homogeneous clusters: orchestration (n=18), enrichment (n=23), adjunct instruction (n=14), and drill and practice (n=5). Teachers in the orchestration cluster emphasized both basic skills and conceptual goals; integrated microcomputer-based instruction with the current subject matter, and coordinated class and computer activities closely; and employed multiple modes of instruction on the computers. Teachers in the enrichment cluster were least inclined to integrate computer-based instruction into the curriculum. They emphasized something akin to computer literacy within a limited instructional program. Teachers in the adjunct instruction cluster were distinguished by their grouping of students for microcomputer-based instruction to selectively augment certain lessons. Finally, the five teachers in the drill and practice cluster were very homogeneous in their extensive and almost sole use of drill and practice programs that were integrated with the ongoing curriculum and closely coordinated with classroom instructional activities, and in their not having changed computer use since implementing microcomputers.

The similarities among these teachers, regardless of cluster, are equally informative. In general, the teachers did not stress the use of microcomputers for motivating students or for keeping students' records or testing them. They typically assigned equal amounts of time at the microcomputer to all students--about an hour per week. Most had established rules regarding the operation of the computer and regarding talking while working with the computer. Most teachers assigned material to students on the microcomputer by matching content/difficulty and (less typically) by matching instructional mode to student need; they were also opportunistic, assigning students to special software when it became available. Finally, over two-thirds of the teachers reported that their schools and districts provided courseware and that they participated in courseware selection decisions.

The third conclusion is that this diversity in the patterns of microcomputer-based instruction is probably due to a number of factors such as teachers' attitudes toward computer-based instruction, their knowledge of subject matter and of computers, and the context in which they teach. By context we include the nature and needs of their students, and the policies and support of district and school administrators. Until such factors are considered, an overall evaluation of the different patterns of microcomputer-based instruction is premature.

IV. CHARACTERISTICS OF COMPUTER-USING TEACHERS AND THEIR DISTRICT, SCHOOL, AND CLASSROOM CONTEXTS

Patterns of microcomputer-based instruction systematically varied among the sample of 60 "successful" teachers. Roughly 30 percent orchestrated microcomputers in an ongoing stream of instruction, 38 percent used them to enrich students' experience with them, 23 percent provided adjunct instruction, and 8 percent coordinated drill and practice programs with instruction aimed at developing mastery of basic skills. These variations may be associated with teacher characteristics such as their attitudes toward computers, their knowledge of the subject matter taught, or their knowledge of microcomputers themselves. Variations may also be associated with district implementation and support policies and school building resources and incentives. Classroom conditions, such as the nature of the students served or the proximity of microcomputers to the classroom, represent still another possible influence on microcomputer use.

Information on the relative influence of these possible sources of variation in microcomputer-based instruction may have an important bearing on policies regarding teacher *selection* and *training* for school districts seeking widescale implementation of computers for instruction. For example, information about teachers' attitudes toward computers and subject-matter backgrounds might, among other kinds of information, enter into a district's decision about the types of teachers it seeks to hire or train. Moreover, information about the nature of teachers' computer knowledge that distinguishes among different instructional practices might be used, along with other information, to establish a curriculum for preservice education or inservice staff development.

Individual differences among teachers in their attitudes and knowledge, however, do not and cannot account for all the systematic variability in instructional uses of microcomputers. There are contextual factors that encourage, discourage, or set limits on the kinds and range of instructional uses teachers may employ. School district policies regarding the amounts and kinds of hardware and courseware might influence computer use. School-building policies that support and encourage computer use might affect the prevalence and kinds of use. The nature of the students served in the classroom might affect the modes of microcomputer-based instruction. Taken together, these contextual factors might lead to different teacher *selection* and *training* decisions; that is, selection and training decisions might very well depend on the particular context in which instruction occurs.

Information about teacher attitudes and knowledge, and the classroom contexts in which they teach may have social policy implications as well. There is growing concern over "computer equity," equity of access to the new technology, the knowledge and skills needed to use it, and the roles this technology can play in society (e.g., *The Computing Teacher*, 1984; Becker, 1983; Lipkin, 1982; Reisner, 1983; Walker, 1983). Our data can be brought to bear on claims that, for example, low income, minority students have less access to microcomputers and that they receive systematically different kinds of instruction on the machines than do other students.

In this section, we examine the relationship between instructional practices as represented by the teacher clusters and teachers' (a) instructional contexts, (b) attitudes towards computers, (c) subject-matter knowledge, and (d) computer knowledge.

DISTRICT AND SCHOOL CONTEXT

The way in which a district and its schools implement an educational program has profound effects on that program's impact and longevity. Based on an extensive study of the implementation of federally funded demonstration programs in new locales, Berman and McLaughlin (1978) concluded that the essential ingredients of a successful implementation were: (a) program support at all levels of the institution (district, school, and teachers), (b) mutual program adaptation where the program is adapted to and supported in the local context by teachers and administrators alike, and (c) institutionalization where the program becomes part of the educational repertoire of the district.

These conclusions are no less true for implementing computers in science and mathematics instruction (e.g., Becker, 1984; Hall, 1981; Romberg and Price, 1981). Sobol and Taylor (1980) described the implementation of microcomputers in the Scarsdale school district: (a) a corps of teachers urged exploration of computer use and this grassroots plea found support systemwide; (b) implementation led to new roles for participating teachers and students; and (c) institutionalization was still an issue to be resolved at the time of the report.

Recognizing the potential importance of the district and school context, we collected data on the extent to which the 25 districts supported the implementation and the instructional use of microcomputers, and on the extent to which the 49 schools (principals) supported and provided incentives for microcomputer use. (These support and incentive variables are defined in Table 4.1).

For each district- and school-level variable, we examined differences among the patterns of instructional uses. Could the teachers in the orchestration cluster be distinguished from teachers in the drill and practice cluster by district policies and support for microcomputers? Could teachers in the enrichment cluster be distinguished from those in the adjunct instruction cluster based on school-level support and incentives for microcomputer-based instruction? Without exception, the answer to these questions was "no" (see Table B-6 in Appendix B).

Overall, most teachers were found in districts where (a) the impetus for computers came from the teachers alone or in conjunction with school and district administrators; (b) microcomputers were supported, at least to some extent; but (c) microcomputers were not included in the district budget as a line item. About half the teachers were drawn from schools that provided personnel support for microcomputer use, and roughly two-thirds were offered some kind of incentive for using them--primarily release time to attend computer workshops. Finally, the teachers worked in schools where an average of about 12 microcomputers could be found for instruction, considerably more than the average of 1 per school we estimated nationwide based on data provided by NCES (1982).

Table 4.1

DEFINITION OF CONTEXT VARIABLES

Variable	Source of Information	Definition
DISTRICT		
Routine support	District interview	Whether or not the district routinely supports instructional computer use (0=no, 1=yes)
Implementation	"	Whether or not the impetus for computers came from administrators (0,1)
Funding	"	Whether or not computers are a line item in the districts budget (0,1)
SCHOOL		
Resources	Principal interview	Whether or not school resources (monetary and personnel) are available for computer use (0,1)
Incentives	"	Whether or not the school provides incentives for teachers to use computers (0,1)
Release time	"	Whether or not the school provides release time for teachers to learn about computers or develop curricular materials for computers (0,1)
Pay	"	Whether or not the districts provide financial incentives for computer use (0,1)
Home	"	Whether or not the school permits teachers to take home computers to learn about them and develop curricular materials (0,1)
Recognition	"	Whether the school provides special special recognition for computer use (0,1)

Table 4.1

DEFINITION OF CONTEXT VARIABLES
(continued)

Variable	Source of Information	Definition
Number of microcomputers in school	Principal interview	Number of microcomputers in the school
Physical location	"	Physical location of microcomputers in the school
CLASSROOM		
Minority	Teacher interview	Percent minority in students classroom
Ability	"	Ability level of students (1=low, 2=middle, 3=high)
Grade	"	Elementary (1) or secondary (2)
Proximity	"	Proximity of microcomputer to classroom (1=in class or attached to class, 2=lab)
Number of micro-computers	Teacher interview and observation	Number of microcomputers available to the teacher for instructional use

One possible explanation for this lack of differences is that we either measured the wrong variables or measured the right variables inadequately. Both alternatives have merit. For example, characterizing a district's financial support for microcomputers by whether or not computers were a budget line item provided too gross a characterization. A finer-grained measure, such as the number of microcomputers purchased out of Chapter 1 monies, might better have reflected the district's policy and support.

A second explanation, one that we find equally or more plausible, is that the burden and psychic rewards for instructional uses of microcomputers rest squarely on the shoulders of those computer-using teachers who were nominated by their peers and others as unusually successful. Regardless of the degree of support--and most districts and schools in the sample supported microcomputers to some degree--the energy, interests, and instructional proclivities of the teachers (and, as we shall see, the students taught) may have been most influential. In short, variation in instructional use is more a function of the teacher and classroom context than district and school policies, support, and incentives.

CLASSROOM CONTEXT

The organization and composition of students in the classroom profoundly affects instructional processes and outcomes (e.g., Borko, Shavelson, and Stern, 1981; Burstein, 1980; Barr and Dreeben, 1977; Walberg, 1976; Webb, 1980). To what extent are variations in microcomputer-based instruction related to classroom organization and student composition? Is Lipkin (1982, p. 7) right in warning that "the urban, low-income minority student ... is most likely to be provided with drill and practice...while middle class students are more likely to use it for more creative purposes relating to problemsolving [sic] and discovery"?

We collected data that bear on the relation between classroom context and microcomputer-based instruction in a limited way. With regard to composition, teachers estimated the percent of minority students in their classes and the ability level of their students. (See Table 4.1 for definitions of these variables.) (Shavelson (1983) presents evidence that teachers are reasonably accurate in their estimates of, for example, student ability. The reliability with which the interviewers determined classroom ability from their interviews with teachers was 0.95 for a single interviewer.) As for organization, teachers indicated and we observed the number of microcomputers available for instruction and their proximity to the teachers' classrooms (see Table 4.1). Finally, since elementary schools are organized around self-contained classrooms and secondary-school classrooms are organized by subject matter, we included grade level as a third organizational variable.

Instructional use proved to be unrelated to the organizational variables (see Table 4.2). On average, about five computers were *available* for teachers to use (in contrast to an average of 12 per school), but this number varied greatly from one teacher to the next. Slightly over half of the teachers took their students to laboratories to receive microcomputer-based instruction. Variations in this instruction were not systematically related to grade level.

Table 4.2

COMPARISON OF TEACHER CLUSTERS AS TO CLASSROOM CONTEXT
[Means and (Standard Deviations)]

Variable	Cluster [a] 1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	All (n=60)	Statistically Significant Contrast [b]
ORGANIZATION						
Number of micro-computers	4.59 (4.80)	5.78 (6.81)	2.92 (4.08)	8.80 (6.98)	5.09 (5.83)	ns
Proximity to microcomputer	1.25 (0.45) (n=16)	1.18 (0.39) (n=22)	1.09 (0.30) (n=11)	1.40 (0.55)	1.20 (0.41) (n=54)	ns
COMPOSITION						
Percent minority	19.94 (24.74)	42.57 (32.02)	44.93 (32.39)	64.40 (35.30)	37.98 (32.31)	1<4
Ability level	2.22 (0.55)	2.09 (0.67)	2.00 (0.88)	1.20 (0.45)	2.03 (0.71)	1,2>4

[a] Cluster size is indicated by variable only when missing data are encountered.

[b] Level of significance, based on one-way analysis of variance, was set at α=05. Pairwise comparisons are based on Tukey's HSD test with unequal sample sizes (α=.05); numbers refer to cluster numbers. Proximity and number of micros (r=0.72), and percent minority and ability level (r=0.56) were significantly correlated (see Table B-7 in Appendix B).

In striking contrast is the finding that variation in microcomputer-based instruction was related to classroom composition. Both percent minority and ability level were associated with variation in instruction. Specifically, classrooms with students above average in ability and low in number of minorities tended to be found with teachers characterized as "orchestrating" the ongoing curriculum with a wide variety of microcomputer-based instructional modes stressing both skill acquisition and conceptual knowledge. As the ability level decreased and percent minority increased, microcomputer-based instruction tended toward "enrichment" and "adjunct instruction." The five classrooms with a high percentage of minority (mean = 64.40) students low in ability (mean = 1.20 on a three point scale) employed microcomputers to deliver drill and practice on the basic skills taught in class.

The results of this study, then, support Lipkin's and others' (e.g., Becker, 1983; *The Computing Teacher*, 1984; Reisner, 1983; Walker, 1983) concerns that microcomputer-based instruction might systematically differ as a function of income level, and minority and ability status. Indeed, these findings are consistent with those of a newly published study in which the National Science Foundation concluded that "[o]pportunities for computer learning in our nation's schools are increasing, but 'ominous inequities' continue based on many factors, including social status, gender, and geographic location" (National Science Foundation, 1983).

Although there is substantial evidence that low-achieving students need instruction and practice in basic skills, if this is all they receive from microcomputers, their encounters with microcomputers clearly distinguish them from average or above average students. Put another way, if the "medium is the message," students in classrooms characterized by low ability and a high percent of minority students might well learn that microcomputers exist to drill them while other students might learn that the machines can serve a variety of functions including tutor, tutee (e.g., programming a computer), or tool (using the microcomputer to solve problems), depending on their goals and needs. Such concern is echoed in the Carnegie Commission on Teaching's admonition that "[t]he challenge is not learning how to use the latest piece of hardware but asking when and why it should be used."

ATTITUDES

A popular myth is that most teachers have negative attitudes toward technology, including microcomputers. This is simply not true. A national survey of a sample of 1200 NEA teachers found that 83 percent of the teachers were at least "somewhat" interested in learning about instructional computer use and 63 percent were "moderately or very interested" (National Education Association (NEA), 1982; see also *Instructor*, 1982).

Our data are consistent with the NEA's. Teachers nominated as unusually successful computer users held uniformly positive attitudes regardless of differences in their microcomputer-based instruction (Table 4.3). Indeed, all but a few teachers indicated they were extremely positive toward computers and that they would like very much to own (or do own) a microcomputer.[1]

KNOWLEDGE

One might reasonably expect that the greater a teacher's *subject-matter* knowledge, especially in science and mathematics, the greater the integration of microcomputer-based instruction with the subject matter and coordination with other instructional activities. Or, one might expect that the greater the teacher's knowledge of *computer* hardware and courseware, the more likely he or she would be to use a variety of instructional modes. Although these expectations are certainly plausible, at least intuitively, we bring empirical data to bear on them.

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[1] Teachers were asked to indicate, on a four point scale (1=strongly disagree ... 4=strongly agree), their agreement with the following two statements: "I have a positive attitude toward computers," and "I would like to own (or do own) a computer." Since most teachers responded with a 3 or 4, we coded any response below 4 as 0 and a response of 4 as 1. The two items were summed to produce a scale from 0 to 2 with a reliability of 0.75.

Table 4.3

COMPARISON OF TEACHER CLUSTERS ON ATTITUDES
TOWARD COMPUTERS AND SUBJECT-MATTER KNOWLEDGE

Variable	Cluster				All	Statistically Significant Contrasts [a]
	1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	(n=60)	
Attitude toward computers [b]	1.83 (0.51)	1.78 (0.52)	1.64 (0.74)	1.80 (0.45)	1.77 (0.56)	ns
Percent undergraduate coursework in						
Science	14.00 (13.00)	18.43 (14.96)	35.93 (23.08)	46.80 (22.02)	23.53 (20.06)	see Fig. 4.1
Mathematics	16.72 (14.83)	15.78 (14.11)	15.21 (10.66)	12.60 (9.29)	15.67 (13.02)	ns
Computer science	1.50 (3.73)	1.22 (3.13)	0.07 (0.27)	1.00 (1.41)	1.02 (2.85)	ns
Social science	26.17 (22.90)	15.35 (18.32)	16.50 (15.31)	7.00 (3.74)	18.17 (19.05)	ns
Humanities	21.61 (20.11)	20.70 (19.36)	20.36 (17.85)	23.40 (16.21)	21.12 (18.57)	ns
Education	15.50 (14.34)	15.96 (15.07)	7.93 (13.52)	3.20 (4.15)	12.83 (14.32)	ns

[a] Level of significance, based on one way analysis of variance, was set at $\alpha=.05$.

[b] Sum of ratings on a 4-point scale, converted to a 2-point scale; total score range is 0 to 2.

Subject-Matter Knowledge

Long ago research established the counter-intuitive fact that students' achievement was not systematically related to their teachers' subject-matter knowledge (e.g., Gage, 1963). One reason for this finding, among several, is that textbooks may compensate for variation in teachers' knowledge; if students do not learn a fact or concept from their teachers, they may learn it from their textbooks. Surprising, yet germane to this study, is the fact that research has not examined the relation between teachers' knowledge and the method and content of their classroom instruction. Could it be that subject-matter knowledge might account, in part, for variations in instruction, especially microcomputer-based instruction?

The first requirement to begin to answer this question is a measure of teachers' knowledge of the subject-matter they taught, which is not obtained easily or unobtrusively. In lieu of direct and extensive testing, we settled for a proxy measure of knowledge. We asked the teachers to indicate the percent of their undergraduate coursework spent in science, mathematics, computer science, social science, humanities, and education.[2] We then examined the relation between these indicators of subject-matter knowledge and patterns of instructional uses of microcomputers. By and large, our findings corroborated those of research on the relation between teacher knowledge and student outcomes: there were no systematic differences among clusters in terms of the average percent of coursework taken in mathematics, computer science, social science, humanities, and education (Table 4.3).

Instructional use, however, systematically varied as a function of the amount of science taken as an undergraduate (Table 4.3). Teachers in the drill and practice cluster took, on average, considerably more coursework in science than teachers in either the orchestration or enrichment cluster.

The percent of undergraduate coursework also varied as a function of grade level. Not unexpectedly, secondary mathematics and science teachers took, on average, more coursework in science, mathematics, and computer science than did elementary teachers. Elementary teachers, however, took more courses in social sciences and humanities, on average, than did secondary teachers. The difference in elementary and secondary teachers coursework in education was not statistically significant (α=0.05).

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[2] We also asked teachers to indicate their undergraduate and graduate-school majors and the percent of graduate coursework taken in science (etc.) courses. We chose not to use undergraduate major because it was too global a measure (and it correlated, on average, 0.55 with percent of coursework in that major). For a similar reason, we decided not to use graduate major either. Finally, graduate coursework was not used because only about half the teachers had earned a masters degree. The percents, therefore, would represent varying numbers of courses in a subject area for different teachers, depending on how much graduate work they had completed. Moreover, most of the teachers majored in education at the graduate level.

Most importantly, a consistent pattern of differences among clusters emerged when coursework and grade level were considered simultaneously.[3] Teachers in the drill and practice cluster, especially the two elementary teachers, tended to take a considerable amount of coursework in science (Fig. 4.1a). They took little coursework in mathematics (Fig. 4.1b), and even less in social science, regardless of grade level (Fig. 4.1c). In contrast, teachers in the orchestration cluster tended to take, on average, little coursework in science regardless of grade level, but elementary teachers (n=13) in this cluster tended to take considerably fewer mathematics courses and more social science courses than did secondary teachers (n=5). Secondary teachers in the other two clusters tended, on average, to take more science and mathematics, and fewer social science courses than their elementary counterparts.

Computer Knowledge

It seems plausible to expect that teachers who are knowledgeable about computer hardware and software would use microcomputer-based instruction somewhat differently than less knowledgeable teachers. The more knowledgeable teachers, for example, might make fuller use of the hardware's capabilities than less knowledgeable teachers. To what extent do the data bear out these predictions?

As with subject-matter knowledge, we sought a measure of teachers' knowledge that could be obtained relatively easily and unobtrusively with the teachers' cooperation. This ruled out testing. Instead, we asked teachers questions related to how extensively they had used computer hardware and courseware. For example, we asked them about the number of different courseware packages that they had used during the academic year, about the extent to which they used microcomputers outside of their teaching, and about the various pieces of computer

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[3] The following interpretations are based on a cluster by grade level analysis of variance for the variables: science, mathematics, and social science. For all three variables, the cluster by grade level interaction was statistically significant (α=0.05).

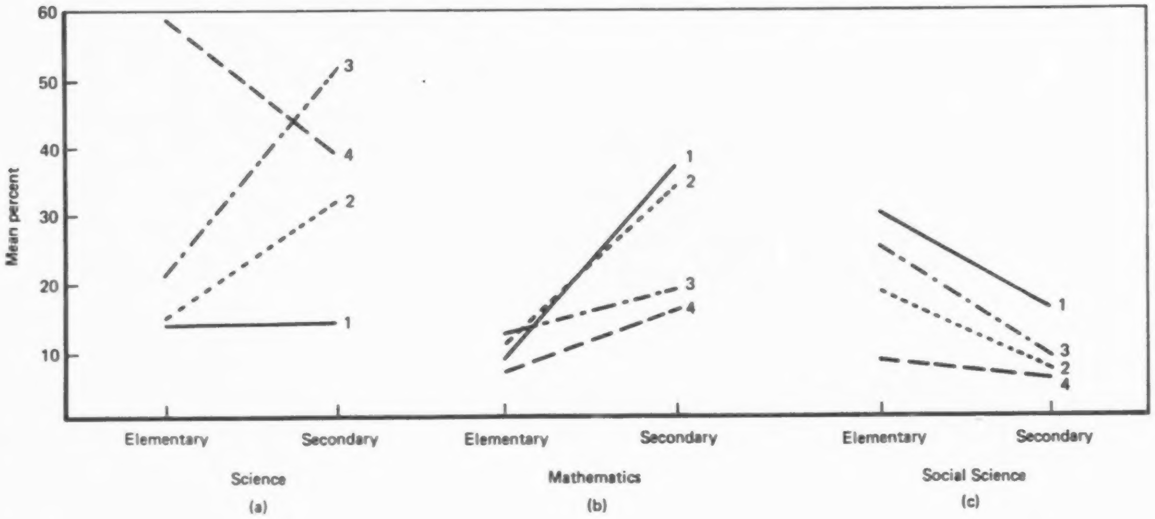

Fig. 4.1 -- Interaction of cluster and grade level for percent of coursework in science, mathematics, and social science

hardware with which they were familiar. We also asked whether they had served as a resource person for their schools, or as an instructor for staff development in microcomputer use. Our rationale was that self-reports of behavior regarding microcomputer use provided experiential indicators of computer knowledge. Also, the interviewers rated each teacher's courseware and hardware knowledge. The specific measures of teachers' computer knowledge are defined in Table 4.4.

The pattern of results presented in Table 4.5 is quite clear: instructional use is unrelated to teachers' experience in using microcomputers and in teaching other teachers about them. The teachers had, on average, used about 25 different courseware packages during the school year,[4] applied computers outside their work in a number of different ways (e.g., word processing, data analysis), used several different types of hardware, and wrote in one or more computer languages (usually BASIC and another language such as Pascal). Approximately 70 percent of the teachers had taught staff development, and 85 percent had served as a school resource person for microcomputer use. In short, regardless of instructional use, these teachers had considerable experience with microcomputers as a whole.

The interviewers' rating of teachers' courseware knowledge, however, did vary systematically with instructional use. Teachers in the orchestration cluster were rated as significantly more knowledgeable about courseware than teachers in the drill and practice cluster. This finding is not unexpected since the latter teachers primarily used just one type of courseware, drill and practice, whereas the former were distinguished from teachers in the other clusters by their uses of multiple modes of microcomputer-based instruction.

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[4] The large standard deviation in cluster 1 (orchestration) is due to the fact that one teacher did not use courseware packages. Rather, he used communications software and data bases on networks such as the Source for instruction. He also received an award as the best microcomputer-using teacher in the state. The large standard deviation in cluster 4 (drill and practice) is due to the fact that several teachers used a very large number of different drill and practice programs.

Table 4.4

DEFINITION OF COMPUTER KNOWLEDGE INDICATORS

Variable	Source of Information	Definition
Disks	Teacher questionnaire	The number of different courseware packages the teacher used for instruction in the past year
Outside	"	The number of different uses the teacher has made of computers outside of teaching (e.g., text editing, computation, testing)
Equipment	"	The number of different types of computer equipment the teacher has used (e.g., floppy disks, hard disks, cassette player, modem, printer)
Taught staff development	"	Whether or not the teacher has taught teachers or district staff about computers (0=no, 1=yes)
Resource person	"	Whether or not the teacher has served as a resource person for computer use in his/her school (0,1)
Courseware knowledge	Teacher interview	Interviewer rating of teachers' courseware knowledge (1=not knowledgeable ... 4=extremely knowledgeable)
Hardware knowledge	"	Interviewer rating of teachers' hardware (computer equipment) knowledge (1 ... 4)

Table 4.5

COMPARISON OF TEACHER CLUSTERS ON COMPUTER KNOWLEDGE
[Means and (Standard Deviations)]

Variable	Cluster [a] 1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	All (n=60)	Statistically Significant
EXPERIENCE						
Number of different courseware packages used	29.67 (34.56)	21.47 (25.88)	21.85 (24.32)	28.80 (40.23)	24.63 (29.14)	ns
Number of uses of computers outside teaching	4.11 (3.34)	3.83 (2.33)	3.29 (2.30)	3.00 (1.58)	3.72 (2.59)	ns
Number of different types of hardware used	2.28 (1.18)	2.35 (1.27)	2.29 (1.20)	3.00 (0.71)	2.37 1.19	ns
Number of computer languages used	1.33 (1.03)	1.30 (1.22)	0.71 (0.47)	1.20 (0.84)	1.17 1.01	ns
Taught staff development	0.78 (0.43)	0.70 (0.47)	0.71 (0.47)	0.60 (0.55)	0.72 0.45	ns
Served as resource person	0.89 (0.32)	0.78 (0.42)	0.93 (0.27)	0.80 (0.45)	0.85 (0.36)	ns
INTERVIEWER'S RATING OF						
Courseware knowledge	3.17 (0.71)	2.59 (0.85)	2.50 (0.90)	2.20 (0.45)	2.72 (0.84)	1>4
Hardware knowledge	3.00 (0.91)	2.76 (0.70)	2.56 (0.73)	2.60 (0.55)	2.75 (0.77)	ns

[a] Level of significance, based on one way analysis of variance, was set at $\alpha=.05$.

CONCLUSIONS

The findings on the relation between patterns of microcomputer-based instruction and teacher characteristics and district, school and classroom context are potentially startling. Paramount is the finding that students in classrooms characterized as low in ability and high in percent minority received computer-based instruction primarily from drill and practice programs while students in classrooms characterized as high in ability and low in percent minority received instruction from a myriad of different types of computer programs including drill and practice, tutorials, simulations, microworlds, and games. If the medium is the message, the message delivered to students in the former classrooms is substantially different from the message received by students in the latter.

Moreover, contrary to the recommendations of the National Science Board's Commission on Precollege Mathematics, Science and Technology Education, science teachers may not be the ones to lead the technology revolution in education if diversity in microcomputer-based instruction is sought. Teachers with extensive undergraduate coursework in science tended to fall into either the adjunct instruction or the drill and practice cluster. Teachers in the former cluster tended to limit computer-based instruction to drill and practice or simulations in the subject matter, while teachers in the latter cluster tended to use solely drill and practice programs for basic skills instruction.

Equally surprising were the findings that, implementation research notwithstanding, district and school policies regarding the support for microcomputer-based instruction were unrelated to the patterns of instructional use. Rather, patterns of use were systematically related to differences in subject-matter backgrounds of teachers, and to the composition of their classrooms. We do not, however, know whether the observed variations in use were "caused" by differences in their academic training; by the needs of their students; by the common educational prescriptions providing highly structured, basic skills instruction for low achieving students and conceptually stimulating, less structured instruction for high achieving students; by some other factor not measured in the study; or by some combination of all of these.

Before jumping to hasty implications for policy, we further analyzed these data taking into account the relationships among the teacher characteristics and classroom context variables. For example, those classrooms with a high percent of minority students were also those with students of lower ability (r=0.56). To this end, we unabashedly set forth, in a post hoc fashion, a model that related cluster membership to (a) percent minority; (b) ability level; (c) grade level; (d) subject matter including percentage of coursework in science, social science, mathematics; (e) courseware knowledge; and (f) several cross-product terms: science x grade level, social science x grade level, and mathematics x grade level. This model was estimated in three steps using logistic regression analysis.

The first step was to contrast the drill and practice cluster with the other three clusters because of its striking differences from especially the orchestration and enrichment clusters. Not surprisingly, teachers in the drill and practice cluster had significantly more undergraduate coursework in science and a significantly higher percentage of minority students (Chi square goodness of fit test; Chi square=22.19, p=.999).

The second step was to contrast teachers in the orchestration cluster with teachers in the enrichment and adjunct-instruction clusters. Teachers in the former cluster were distinguished from teachers in the other two clusters by less undergraduate coursework in science, greater courseware knowledge (as rated by interviewers), and classrooms with fewer minority students (Chi square=50.82, p=.481).

The last step in the analysis contrasted teachers in the enrichment and adjunct-instruction clusters. Teachers in the former cluster had considerably less undergraduate coursework in science than did teachers in the latter cluster (Chi square=42.05, p=.192).

We conclude, then, that there is good reason for concern regarding social inequities in computer-based instruction. Minority students are more likely to receive computer-based instruction with drill and practice programs than are other students. And, for reasons not clear to us, minorities tend to be taught by teachers who have more extensive coursework in science than the other teachers in the sample.

The causal links between teacher characteristics, classroom contexts, and microcomputer-based instruction cannot be disentangled in our data. What we have observed, however, follows from current educational prescriptions of direct instruction in basic skills for low achieving students. Perhaps, as this prescription implies, the microcomputer-based instruction received by minority students is appropriate; research that shows a positive relation between drill and practice and achievement lends credence to this prescription (e.g., Kulik, Kulik, and Cohen, 1980; Kulik, Bangert, and Williams, 1983; Ragosta, 1983). But what if the medium is the message? Then minority students are more likely to be constrained in their knowledge about microcomputers than other students. Moreover, what if the prescription is inaccurate? Such prescriptions might significantly reduce the probability of finding other instructional modes (e.g., simulations, microworlds) that improve the achievement of low achieving or minority students (e.g., Borko, Shavelson, and Stern, 1981; Glaser, 1984).

These findings, then, call into question current educational policy and practice. For example, perhaps science teachers should not be selected as the primary source of leaders in the educational technology revolution. According to our data, if a balance in the nature of microcomputer-based instruction is sought, teachers with backgrounds in the social sciences might be important participants. But our data do not permit us to disentangle curricular background of teachers from the composition of their classrooms. Perhaps, then, the current emphasis on basic skills instruction should be called into question for leading to a too narrow definition of the nature of computer-based instruction. What would happen if conceptual understandings were given greater emphasis and basic skills somewhat less emphasis since there is reason to believe that a complete repertoire of basic skills is not necessary for conceptual understanding? Would a chain of instructional prescriptions change with corresponding improvement in student motivation and achievement, or would student behavior problems increase and achievement drop? We do not have answers to these questions, but research that bears on them should be high on any educational research agenda.

V. STAFF DEVELOPMENT FOR MICROCOMPUTER-BASED INSTRUCTION

The lack of adequately trained teachers presents a major obstacle to the effective instructional use of microcomputers in schools. Stutzman's (1981) census of California school districts, for example, revealed that over 60 percent of the teachers using computers were either unprepared or inadequately prepared, over three-fourths of the districts not using computers reported that faculty had practically no preparation in instructional computer use, and for both using and non-using districts, the lack of adequately trained teachers was second only to the lack of funds as a factor that inhibited development of educational programs in computer-based instruction. Not only is the problem clear, so is the solution--train preservice and inservice teachers to use microcomputers instructionally (cf. Taylor, Poirot and Powell, 1980; Poirot, 1980). The catch comes with the implementation of the solution, viz., educators lack the experience and the research base on which to ground their decisions regarding the selection of topics for training and the organization of this training. To begin to compile a research base for these decisions, we collected "successful" teachers' recommendations for the content and organization of training on the instructional uses of microcomputers, and examined whether these recommendations varied according to differences in the patterns of their microcomputer-based instruction. In this section, we report these recommendations after reviewing that portion of the staff-development literature which bears on the content and organization of teacher training for microcomputer-based instruction. The section concludes with a set of recommendations applicable to preservice education and inservice staff development.

STAFF DEVELOPMENT FOR MICROCOMPUTER USE: RESEARCH AND THEORY

Background

The shortage of teachers trained in microcomputer-based instructional techniques has been documented not only in the United States (e.g., NEA, 1983), but in other nations as well (Cerych, 1982). The solution to this problem has been to provide staff development for implementing microcomputers instructionally. Such efforts, however, typically fall short in the number of teachers trained, in the length of training, in the amount of "hands-on" experience provided in the topics covered, and in the provision of in-class follow up after the staff-development activity. No wonder trainees' effectiveness in using microcomputers falls short of expectations.

A number of factors contribute to these limitations in the effectiveness of staff-development programs. First, microcomputers have entered our schools only recently--about six years ago. Now their numbers are increasing at an overwhelming rate, far outstripping the schools' ability to prepare teachers to use the new technology. In 1983, for example, every school in the state of California received a free microcomputer from the Apple Corporation.

A second factor is the sheer number of teachers who require training. Although the number of computer-related courses offered at teacher-training institutions is increasing, the vast majority of teachers do not receive preservice education in computer use (Issacson, 1981; Chambers and Bork, 1980). For example, in a national survey of 1200 teachers, only 11 percent reported receiving some computer training in college or university (NEA, 1983). Very few schools of education have changed their requirements to ensure that every graduating teacher is competent in the use of microcomputers (NIE, 1981). One study estimated that only five percent of the approximately 1,350 teacher training programs in the country offered such courses (Benderson, 1983).

At a time when the need for teachers proficient in microcomputer use is increasing, the provision of preservice education in this area is hampered by decreasing enrollments in schools of education, and by decreasing federal spending for education. This means that the degree to which preservice teacher-education will fill this great training gap depends less on need than on economics. Teacher-education institutions will make curricular decisions, in large part, on whether enrollment of able men and women will increase if a major investment is made to develop courses and programs in microcomputer applications (Sherwood, Connor, and Goldberg, 1981).

Finally, the third factor limiting microcomputer use is the lack of knowledge about and agreement on the topics and organization of staff-development programs. Districts and schools have employed many different models for staff development, but they lack vital information about factors that lead to successful implementation and effective instructional uses of microcomputers (Sheingold, 1981). For example, what content should be covered in the training? Obviously, teachers need to know how to operate the computer and to load and save instructional programs. But does every teacher need skills in evaluating courseware, in computer programming, and in successfully integrating computers into regular, ongoing instruction?

With regard to the organization of staff-development programs, a number of questions beg for answers: How much training is needed to enable teachers to use microcomputers effectively? Should courses be held locally to ensure better attendance or at a site that accommodates a large number of computers for hands-on practice? Do incentives, such as release time or salary credits, ensure better participation in and implementation of staff-development activities? The paucity of staff-development materials, both in written and computer form, reflects, in part, the lack of systematically derived empirical evidence upon which such materials could be built.

In spite of these limitations, schools of education in their preservice-education programs and school districts in their inservice, staff-development programs are attempting to respond to the demands for training. A major purpose of this study is to begin to provide a conceptual and research base for doing so. We focus on inservice education but our analysis also applies to preservice education.

Framework for Staff Development

Following Fenstermacher and Berliner (1983, p. 4) we defined staff development as "The provision of activities designed to advance the knowledge, skills, and understanding of teachers in ways that lead to changes in their thinking and classroom behavior" regarding microcomputer-based instruction. To place this definition within the organizational context of schools, we assume that staff-development activities may be "internally proposed or externally imposed, in order to effect compliance, remediate deficiencies, or enrich the knowledge and skills of individual teachers or groups of teachers, who may or may not choose to participate in these activities" (Fenstermacher and Berliner, 1983, p. 4). Together, the definition and assumption constitute our framework for understanding what comprises good staff development in microcomputer use, regardless of the particular content of the staff-development activity itself.

A valuable staff-development activity for microcomputer-based instruction must first fit our definition (Fenstermacher & Berliner, 1983). That is, it must enhance knowledge, skills, and understanding in ways that lead to changes in thought and action. The value can be further determined by considering the four important features of the organizational context assumed above--How was the activity initiated? For what purpose? Who participates? How is participation decided? Using these features we can construct a profile of a particular staff-development activity that tentatively predicts whether the activity will serve its intended purposes. (Other criteria will be set forth below.) In general, the literature on staff development predicts that externally imposed activities serving to attain teachers' compliance and requiring them to participate will be less valuable than activities that are proposed, at least in part, by teachers who may choose to participate or not, for purposes of enrichment or remediation.

The applicability of these organizational assumptions can be demonstrated by two contrasting examples of staff-development activities taken from our fieldwork.

Example 1: A district superintendent decided to use profits from school-building sales to purchase microcomputers and placed them in every elementary school. In order to get teachers to use them, the district conducted staff-development activities in microcomputer use for all elementary teachers in the district. An outside consultant was hired to run two four-hour workshops at each site.

Example 2: Ms. Goldsmith, a fifth grade teacher, decided to bring her personal computer to school in order to enrich her students' knowledge about computers and to teach them certain mathematics skills. To this end she had purchased some mathematics drill-and-practice courseware at the local computer store. The children were so enthusiastic about the microcomputer that the principal and other teachers became interested in using microcomputer-based instruction in other classrooms. The School Board approved the use of PTA and discretionary funds to purchase more microcomputers and software. By then, Ms. Goldsmith had become the computer expert at her school, and trained other interested teachers in ad-hoc sessions that were held when 2 or 3 teachers expressed interest. She provided follow-up training when new software arrived or when teachers had specific problems or questions arising from their use of computers.

Within the staff-development framework, we describe the first example as *top-down* imposition of a staff-development activity that was externally initiated for the purpose of enrichment (or compliance), with all teachers participating because attendance was mandatory. The second example may be described as a *bottom-up* approach where staff-development activities were initiated by teachers who participated voluntarily in order to learn about and use microcomputer-based instruction.

The organizational factors contrasted in these scenarios highlight two important issues regarding staff development for microcomputer-based instruction. The first concerns whether top-down or bottom-up initiation of staff development leads to more valued consequences. There is some evidence that the latter provides activities that teachers will more readily view as valuable contributions to their knowledge, skills, and understanding of microcomputer-based instruction (Fenstermacher and Berliner, 1983). This occurs, in part, because the small-scale staff-development activity provided by an experienced teacher can flexibly accommodate other teachers' schedules and adapt to the trainees' needs and problems. In the end, however, successful implementation of staff development requires a balance between teacher and district initiation. Districts need to be involved, for motivational, substantive and financial reasons. Once computers are in place, it also seems reasonable for the district to build on the staff-development activities provided by Ms. Goldsmith to ensure successful implementation of microcomputer-based instruction in other schools.

A second concern is whether participation should be mandatory or voluntary. Although simply mandating a program does not necessarily diminish its potential value, voluntary participation seems to have a more salutary effect on implementation (e.g., Berman and McLaughlin, 1978; Fenstermacher and Berliner, 1983). (When the purpose of staff development is compliance-effecting--e.g., to learn new regulations regarding mainstreaming handicapped children--mandatory participation is probably necessary.) Voluntary participation in staff development for microcomputer-based instruction seems to be a feasible and reasonable approach to staff development, especially for two reasons. First, teachers view staff development as enrichment, something valuable to them and their careers. Second, learning about and using computers typically involves a large commitment of time and energy on the teachers' part, a commitment unlikely to arise from involuntary participation. Finally, some teachers may have legitimate objections to computer-based instruction (e.g., they might teach subjects for which courseware in sufficient number and quality is not available) and so choose not to participate on reasonable grounds.

Considering solely the definition of and assumptions about staff development by themselves, we can make only weak predictions about the value of the activities. Clearly, some activities initiated in a "top-down" manner can be successful, especially if care is taken in enlisting teacher support for them. Fenstermacher and Berliner (1983), however, further specified a number of conditions for staff development which, if met, contribute significantly to the value of such activities and the predictability of their success. The conditions most germane for this study are set forth in Table 5.1 as recommendations for staff-development activities for microcomputer-based instruction.

Table 5.1

RECOMMENDATIONS FOR STAFF DEVELOPMENT IN MICROCOMPUTER-BASED INSTRUCTION

Condition	Recommendation
(1) Sensibility	The activity is consistent with plans teachers have for their work, fits well with classroom circumstances, is timely, and is valued for its utility.
(2) Variability	The activity permits variation in the ways teachers participate and in ways they use what they have learned.
(3) Incentives	The activity provides positive incentives to recipients for their participation, both during the activity and during its implementation in the classroom.
(4) Maintenance	The activity provides systematic and clinical support during the activity and during the period of implementation in the classroom.
(5) Objectives	The activity had clearly stated objectives known to both providers and recipients and clearly related to work demands on the recipients.
(6) Instructor	The activity was staffed by providers who have competence in teaching adults, and the instructor is able to model what it is proposed that recipients do in their work settings.
(7) Application	The content of the activity is sufficiently concrete to make its application to the classroom clear.
(8) Duration	The activity provides sufficient time for recipients to learn, practice, master, and apply the content imparted.

Applying the conditions in Table 5.1 to staff development in microcomputer-based instruction, we define a good staff-development program as one that is designed to enhance the teachers' knowledge and skills in ways that lead to changes in their thinking (planning and decisionmaking) and microcomputer-based instruction. These changes in thought and instruction should be supported throughout the school district by teachers and administrators alike. Such a staff-development program will have clearly stated goals (5)[1] that are consistent with teachers' perceived needs, plans for their work, and classroom teaching conditions (1). The activity should permit variation in the ways teachers participate in the activity and apply microcomputer-based instruction in the classroom (2). The content of instruction on microcomputer use should be concrete (7), and its application to the classroom (or microcomputer laboratory) should be demonstrated by an instructor who is competent in teaching adults and who is able to model microcomputer-based instruction in the context of an ongoing curriculum (6). The duration of the program should permit teachers sufficient time to learn, practice, master, and apply in the classroom or laboratory the knowledge and skills imparted (8). It should provide systematic, clinical support during the activity and during the period of implementation (4). Finally, teachers should receive positive incentives for their participation during the training, implementation, and institutionalization phases of microcomputer-based instruction (3).

Content and Other Organizational Features

While the framework provided by Fenstermacher and Berliner (1983) identified important organizational structures and processes for staff-development activities, it was not intended to identify the content of staff development for microcomputer-based instruction. For this information, plus other insights about organizational issues, we examined literature on staff development for microcomputer-based instruction. As expected, few studies have been conducted on this topic. Those that have been reported tend to be case studies rather than comparative studies that systematically varied important characteristics of training such as the organization, content, instructional method, incentives, and support for microcomputer-based instruction. Hence, we begin by providing snapshots of alternative forms of staff development merely to illustrate some of the range of training alternatives considered to date.

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[1] Numbers in parentheses correspond to recommendations listed in Table 5.1.

The most prevalent form of staff development is the one-shot, short-term workshop for interested teachers. These workshops, often offered at a central site in the district, last 2-3 hours for each session and are carried out over a period of a few days to a week. These workshops are often led by computer-education experts from a local university. Teachers are taught about how to operate the computer and write elementary programs, about the range of courseware available, and, in a limited way, about the selection and/or modification of courseware.

A case study of the first workshops conducted in the Scarsdale school system (Sobol and Taylor, 1980) provides an example of this approach. A professor at Columbia University, Robert Taylor, met with all teachers in the district to provide an overview of contemporary computer technology and its implications for teaching and learning. Interested teachers and administrators were then invited to participate in an in-service course that was scheduled for eight 2-hour sessions. The goals of the course were to alleviate teachers' fears about the computer, to better inform them of some potential uses of computers in the classroom, and to teach rudimentary programming.

A second approach to inservice education in microcomputer-based instruction combines the one-shot, short-term workshop with one or a few additional, focused workshops that are directed to participants' special needs. This approach often includes an introductory course, like the type offered in Scarsdale, with additional courses in more advanced computer programming or non-instructional uses of the microcomputer, such as student recordkeeping. The courses are typically taught by a resource person in the school district.

An example of this type of staff-development activity is provided by the program offered by the Salem, Oregon school district (Page and Wallig, 1983). Workshops differed for teachers and administrators, for school-building "experts," and for the public at large. Staff in schools with computers were given an eight-hour workshop during the summer. The instruction covered the operation of microcomputers, introductory programming, evaluation of courseware, and integration of microcoputer-based instruction into the curriculum. The building "experts" received an additional 30-hour workshop in computer programming that emphasized courseware development. Finally, a 2-hour training session was provided for parents and others in the community.

A third approach is to train a small cadre of teachers who then provide workshops and individualized training in microcomputer-based instruction to their colleagues. The Minnesota Educational Computing Consortium (MECC) provides an example of this approach. Instructional computing coordinators are located throughout each of the regions of the state. These regional coordinators work with teachers who in turn serve as local coordinators for their school districts or education agencies. Instructional coordinators conduct workshops across their regions, using local coordinators as resources. They also hold sessions for local coordinators to demonstrate new courseware and to learn about programs developed locally. Local coordinators act as computer-resource persons in their districts, and conduct introductory workshops. Teachers interested in more advanced topics and courseware authoring and design can attend workshops conducted by the regional coordinator or other MECC staff (OTA, 1982).

In addition to individual case studies of specific staff-development activities, some information about the content and processes of staff development can be obtained from comparisons of case studies. One such analysis was carried out by Sheingold (1981; Sheingold, Kane, and Endreweit, 1983), who systematically compared case-study data from three school districts, focusing, in part, on the content and organization of staff development. With regard to content she found that teachers wanted sufficient time to review courseware and to plan how to match courseware with students' abilities and learning styles. As for organizational factors, time was a critical issue for many teachers. Even those teachers who had access to workshops, courses at nearby colleges, and colleagues or resource personnel knowledgeable in microcomputer-based instruction, sought additional time to personally use the machines so as to adequately plan instruction.

A survey conducted by the National Education Association (NEA, 1983) provided further information on teachers' perceived needs for staff development in computer use. The NEA asked a sample of 1200 computer-using (n=751) and "non-using" teachers to check those topics they were interested in learning more about from a list of 13 topics.

Over half of the teachers expressed interest in: instructional applications of computers, how to operate them, and how to write computer programs. About 40 percent were interested in information on courseware and hardware selection, and on different programming languages. Topics less frequently checked included "curriculum design for computertization [sic], K-12 computer science curriculum, educational policy for computers, computer user network, how to teach computer science, computer history and courseware copyright protections" (NEA, 1983, p. 18). On all but three of these topics, users were significantly more interested in learning about the computer-related topics than were non-users. The three topics on which the percentage of interested users and nonusers did not differ were: educational policy (25.3 and 20.8 percent, respectively), hardware selection (38.7 and 40.2), and computer operation (57.3 and 58.9). These findings might reflect differences in needs, not just interests, so that topics included in staff-development programs might vary according to teacher experience or computer expertise. As noted above, some school districts already provide different staff-development programs for inexperienced computer-using teachers and "building computer experts" (Page and Wallig, 1983).

The findings from the review of staff-development approaches, research on staff development for computer use, and the NEA survey are summarized as a set of recommendations for the content and organization of staff development in microcomputer-based instruction in Table 5.2. The topics--microcomputer operation, computer programming, computer literacy, and selection and evaluation of courseware--might form the core of a staff-development program. Other topics are not necessarily less important, but perhaps reflect the extensiveness and variety of information that can bear on microcomputer-based instruction. The variety reflected by these remaining topics highlights the importance of organizing different staff-development activities based on teachers' needs.

Table 5.2

TOPICS AND ORGANIZATIONAL FEATURES OF STAFF DEVELOPMENT
FOR MICROCOMPUTER-BASED INSTRUCTION [a]

Topics

(9) Operation of the microcomputer and peripherals
(10) Computer programming
(11) Selection and evaluation of courseware
(12) Modification of courseware
(13) Computer literacy (e.g., history, types of programming languages)
(14) Non-instructional uses of the microcomputer (e.g., computer-based management)
(15) Integration of microcomputer-based instruction into the curriculum
(16) Design and authoring of courseware
(17) Match of courseware with student abilities and learning styles
(18) Selection of hardware
(19) Computer science curricula and teaching computer science
(20) Development of a user network
(21) Copyright protection issues
(22) Instructional uses of microcomputers

Organizational Features

(23) Staff development located at a central site
(24) Staff development provided in either single or multiple sessions, (25) depending on topics covered
(26) Instruction provided by outside consultant, teacher or district personnel who meets the instructor condition (6)
(27) Training adapted to teachers' needs and interests
(28) Extensive hands-on practice provided

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[a] Numbers in parentheses denote recommendation numbers and are referred to in the text.

Summary of Important Issues and Recommendations

The topics and organizational features (Tables 5.1 and 5.2) provide a beginning for formulating recommendations for staff development in microcomputer-based instruction. Before considering the recommendations made by teachers in our study, we highlight some issues and recommendations that we deem to be particularly important or that have been emphasized in the literature.

Perhaps the most hotly debated issue is whether to include computer programming in introductory staff-development activities that have, as a goal, providing teachers with the knowledge and skills needed to use microcomputer-based instruction. While some advise that instruction in programming at the introductory stages is to be avoided (e.g., Hamolsky, 1983; Nanson, 1982), others assert that programming is essential for teachers (or anyone) to become computer literate (e.g., Luerhmann, 1981). Between these extremes are those who advocate some introduction to a programming language (usually BASIC) as a way to understand the nature of computers and programming (e.g., Page and Wallig, 1983; Widmer and Parker, 1983).

This issue is part of a larger concern on the part of educators and others to define computer literacy. However, the lack of a generally accepted definition of literacy has not prevented interested groups from declaring minimum competencies which all teachers should have to teach effectively in a society permeated by computers (Poirot, 1980; Benderson, 1983). For example, a report by the Elementary and Secondary Schools Subcommittee of the Association for Computing Machinery asserts that teachers should be able to read and write simple programs that work correctly and understand how programs and subprograms fit together into systems (ACM, 1980). We suspect that this issue will intensify as more teacher education institutions begin to require computer courses in their preservice programs (e.g., Ramquist, 1983), and as states consider computer training as a prerequisite for obtaining teaching credentials.

The teacher decisionmaking perspective that guides this study suggests a second essential content area for staff development. Namely, teachers need enough information about the computer and courseware to make reasonable decisions for integrating microcomputer-based instruction into the ongoing curriculum. Although integration is an important element of successful use, our review found few examples of staff development that included this topic.

The most pressing organizational issue concerns teacher incentives. Presently, some school districts use a variety of incentives to maximize teacher participation in staff-development programs, outside computer courses, conferences and other activities that broaden their computer experience and expertise. These incentives include incremental salary credit (Sheingold et al., 1981; Page and Wallig, 1983), reimbursement for outside courses (Coburn et al., 1982), release time (NEA, 1983; OTA, 1982), and new job titles with higher salaries for technically experienced teachers (OTA, 1982). After initial training, other organizational incentives, such as providing computer-resource personnel (Sheingold et al., 1981), loaning computers to teachers over weekends, vacations and summers (Sherman, 1983), and subsidizing teachers to author courseware (OTA, 1982), encourage teachers to continue building their computer knowledge. While most of the evidence indicates that incentives motivate teacher participation in staff development and encourage their continued interest in microcomputers for instruction, little is known about which incentives (or combination of them) are most effective. Because preparing teachers to use microcomputers, as in preparing anyone to learn a new skill, involves a personal investment of time and energy, it is important to examine the incentives for such an investment (Sheingold et al., 1981). Research has shown that some incentives, such as salary credits, are meaningless to teachers who have already reached salary limits (Sheingold et al., 1981). Indeed, better working conditions may be even more important to teachers than higher salaries (Boyer, 1983). The incentive issue is particularly timely, since state policymakers are either considering or enacting legislation on various teacher incentives, such as merit pay for teachers who reach certain standards of excellence, and financial support for current teachers to upgrade their skills and knowledge. Such incentives are expected to aid recruitment, retention, and retraining of highly qualified teachers in mathematics, science, and technolgy.

TEACHERS' RECOMMENDATIONS FOR STAFF DEVELOPMENT

We asked teachers to describe their ideal inservice-training program for microcomputer-based instruction. More specifically, we asked them to comment on the content or topics that should and should not be included in staff development for microcomputer-based instruction, and on organizational features of such staff development, especially location, duration, and incentives. We also asked whether the content of preservice education should differ from that of inservice education, and, if so, in what ways.

The questions were open-ended because we sought breadth and creativity in response. All of the teachers' content recommendations were coded into predetermined categories, based on the content of staff-development programs reported in the literature and on our framework for staff development.

Our analyses initially focused more on whether staff-development recommendations varied systematically according to teachers characterized by grade level and different patterns of microcomputer-based instruction (cluster membership) than in the frequency with which teachers concurred on various topics or organizational features. We expected, for example, that elementary and secondary teachers might have different staff-development needs because of the obvious organizatinal differences between the two levels. Furthermore, teachers who orchestrate microcomputers with the ongoing curriculum might have different recommendations for staff development than teachers who use the computer primarily for drill and practice. Teachers in the orchestration cluster, for example, might suggest integration of multiple instructional uses as an important topic, while their colleagues in the drill and practice cluster might recommend previewing and selecting courseware to fit into their curricula.

Although the data lend themselves to groupings by grade level and cluster, the frequency counts for any particular recommendation are often too small to permit statistical tests. We performed such tests whenever feasible. Thus the patterns of data reported must be considered tentative. Our goal here is to show the range of teacher responses and to provide as much information as possible about teachers' ideas on staff development. The data and patterns of responses might suggest possible relationships among grade levels, teaching methods, and staff-development needs that could be more directly and more systematically tested in future studies.

Content Recommendations

Teachers' recommendations for the content of staff development, shown in Table 5.3, did not, by and large, differ by grade level or patterns of instructional use. The topics most frequently mentioned by teachers were consistent with the findings of the literature review: operation of the microcomputer, computer programming, selecting and evaluating courseware, instructional uses of the microcomputer, computer literacy, and integration of the microcomputer with instruction. They were less concerned about administrative uses. Other topics mentioned by teachers were modification of existing programs, word processing, on-line databases, utility programs, and starting a computer club. These exemplary teachers, then, recommended essentially the same "core" topics for staff development as reported in the literature.

That some teachers did not want programming included in staff development is noteworthy, both because of the controversy surrounding its inclusion in training for instructional uses of microcomputers, and because it was the only topic to receive any definite "no" votes from the teachers. Moreover, 18 teachers, mostly elementary teachers, did

Table 5.3

TEACHERS' RECOMMENDATIONS FOR STAFF DEVELOPMENT TOPICS
(Frequencies)

Item[a]	Cluster 1 (n=18)	Cluster 2 (n=23)	Cluster 3 (n=14)	Cluster 4 (n=5)	All
(10) Programming	10	11	7	2	30
(29) No programming	3	5	2	2	12
(9) Operation of microcomputer	13	17	12	5	47
(11) Selection/evaluation of courseware	10	12	7	1	30
(22) Instructional uses	7	12	7	3	29
(13) Computer literay	10	9	7	2	28
(15) Integration with instruction	4	8	8	2	22
(14) Administrative uses	3	6	1	0	10

[a] Numbers in front of each item refer to recommendations set forth earlier.

not mention programming at all. This suggests that elementary teachers did not consider programming important enough to include it as a topic in staff development for microcomputer-based *instruction*.

In general, teachers' recommendations mirrored the content of staff-development programs provided by the districts and schools in our study. Since these teachers were the "cream-of-the-crop" microcomputer users, they were often placed in a decisionmaking role regarding microcomputer-based instruction in their district or school. Interviews with district personnel revealed that teachers had *primary* decisionmaking responsibility for staff development in over one-third of the districts, and they participated in committees which planned staff development in another one-fourth of the districts. For the most part, teachers expressed satisfaction with staff development provided, and thus were not inclined to change.

Organizational Recommendations

Teachers' recommendations regarding the organizational features of staff development (Table 5.4) can be summarized succinctly as a series of meetings, held during school hours or after school, located on-site, averaging about 13 hours in duration with as much hands-on practice as possible. One additional recommendation was to involve students in the staff-development activity as a way to see how the courseware works with its intended audience. (See Section 6 for a similar recommendation.)

The teachers also recommended varying staff-development activities in level of sophistication and topic, in order to meet the needs of teachers at different stages of microcomputer use. For example, they suggested offering programming as more advanced instruction for teachers who wanted to learn that skill. And they recommended organizing workshops around specific topics so that teachers could attend only those sessions that fulfilled their needs.

Fewer than half of the teachers mentioned staff-development incentives; of these, one-third said they were not necessary. Teachers who opposed incentives felt that they would encourage some teachers to become involved for the wrong reasons. Teachers who supported incentives thought salary credits or release time should be given. One

Table 5.4

TEACHERS' RECOMMENDATIONS FOR ORGANIZATIONAL FEATURES OF STAFF DEVELOPMENT

Item[a]	Cluster 1 (n=18)	Cluster 2 (n=23)	Cluster 3 (n=14)	Cluster 4 (n=5)	All
(23) Location: on-site	7	8	6	2	23
(23) Location: near-by	6	1	2	1	10
(29) Location: with many computers	4	3	1	0	8
(30) Length: follow-up	2	0	0	0	2
(31) Length: ad-hoc	1	2	0	1	4
(32) Length: ongoing	1	2	0	0	3
(24) Length: one-meeting	1	2	0	1	4
(24) Length: many meetings	14	9	9	3	35
(27) Individualize: many levels	3	2	2	0	7
vary topics	1	2	1	0	4
(3) Incentives: recognition	0	1	1	0	2
salary	7	13	5	2	27
release time	9	5	3	1	18
(33) Participation: voluntary	1	1	1	0	3
mandatory	0	2	0	0	2
(6) Provider: teacher	1	2	0	0	3
consultant	0	0	0	0	0
(34) Time: during school	1	1	2	0	4
after school	3	3	0	0	6
weekends	0	0	0	0	0
vacations	0	0	0	0	0
(28) Hands-on practice	4	4	2	2	12

[a] Numbers in front of each item refer to recommendations set forth earlier.

unique suggestion was to give credits to purchase computers or courseware.

Few teachers mentioned whether participation in staff development should be mandated. Research and conventional wisdom suggest that the goals of staff development will more likely be met if teachers choose to participate (Fenstermacher and Berliner, 1983). We found that voluntary participation in staff development for microcomputer-based instruction was almost always the case, although subtle pressures to participate were apparent in some districts. On the other hand, teachers were nearly unanimous in recommending that microcomputer training be mandatory in preservice education.

Recommendations for Preservice Training

Almost all teachers recommended incorporation of microcomputer-based instruction in preservice education programs. Some said that computers should be included as part of the audio-visual block, while others felt that a semester-long course on computers should be offered.

About half felt that preservice training programs should differ from inservice staff development. Some recommended more breadth in the preservice course, such as learning about and comparing different types of computers, and exploring the variety of ways that computers can be used as teaching tools.

Teachers' recommendations for instruction on programming reflected the current controversy. Their recommendations varied widely, from "an introduction in BASIC to understand the concept of programming" and "enough to be able to modify programs" to "skill in one or two languages...secondary teachers should learn Pascal." An equal number of teachers felt that programming was not at all necessary, or that programming should be required only if it applied to the teacher's subject specialty, such as mathematics or science.

Finally, teachers recommended that preservice training in microcomputers be taught by a practitioner who actually used computers in the classroom and that students visit schools using microcomputer-based instruction.

RECOMMENDATIONS FOR STAFF DEVELOPMENT IN MICROCOMPUTER-BASED INSTRUCTION

By considering the literature on staff development, case studies of staff development for microcomputer-based instruction, teacher surveys, recommendations and admonitions obtained from the 60 microcomputer-using teachers in our study, and our observations, a set of recommendations was derived for staff development in microcomputer-based instruction. Many recommendations have already been incorporated into staff-development programs; others are rarely included. Many might be implemented in more than one way, reflecting, in part, district philosophy and resources. Accordingly, these recommendations are not strict prescriptions for staff-development programs. Planners need to consider the recommendations and design staff-development activities that best meet their needs and resource constraints.

Recommendations on the Organizational Features of Staff Development

Our conceptual framework provides one way to appraise the value of the organizational features of staff development, both for those activities planned ("forward-looking evaluation") and those activities that have already taken place ("backward-looking evaluation"; Fenstermacher and Berliner, 1983). The framework, when applied for evaluative purposes, includes matching a staff-development activity against the definition of staff development, the salient organizational features of staff development, and the specific conditions that contribute to a valued staff-development program. Our application of this framework as well as data reported in the literature and collected from our sample of teachers led us to consider a number of organizational recommendations, which we repeat and, when needed, elaborate here.

Participation in staff-development activities should, whenever feasible, be voluntary (33).[2]

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[2] Numbers in parentheses refer to tabled recommendations.

Initiation of staff-development activities should be a collaborative effort of teachers and administrators. This links financial decisions to the needs and experiences of teachers implementing microcomputer-based instruction. Teachers collaborating provide added support for one another (4).

The *objectives* of a staff-development activity should be clearly stated and known to both providers and participants (5); indeed, we recommend that both parties have input into the definition of objectives. These objectives would reflect both teachers' needs and district goals for microcomputer-based instruction.

The *sensibility* condition of our framework leads to the recommendation that the staff-development activity should meet teachers' needs and plans for their work in a timely manner (1).

The *application* of the content of staff-development activities to microcomputer-based instruction in the classroom or laboratory should be clear and concrete (7). This includes provision of courseware that is immediately applicable to the teachers' instructional needs. One teacher aptly admonished, "give teachers something they can do on Monday."

The *variability* condition of our framework leads to the recommendation that the staff-develpment activity permit teachers to decide whether they will participate, how long they will participate, and how they will apply what they learn (2). Teachers recommended a number of ways this might be accomplished. One way is to individualize instruction as much as possible (27). Another way is to focus each staff-development workshop on a different topic, and to offer programming as a more advanced course for those teachers interested in acquiring this skill. For example, districts might offer courses at different levels, beginning with the core courses (9, 10, 13) and ending with advanced programming. Individualization of staff-development activities, by whatever method, should also help meet the conditions of sensibility (1) and application (7).

The ideal *instructor* is, preferably, someone who is or has been a teacher with extensive experience in microcomputer-based instruction in the classroom and laboratory (7). He or she should be an expert on computers and instructional uses of them, and competent in teaching adults. The instructor should be viewed as competent by participants, but not "too technical" or out of touch with the intended beneficiaries of microcomputer-based instruction--the students.

The *duration* of the staff-development program should be sufficient to permit teachers to learn, practice, master, and apply the skills imparted (8). Although the actual time will vary according to the design of the program, our observations and the literature suggest that relatively little time has been devoted to introductory activities--8 to 10 hours spread over three or four sessions is typical. Although this may be sufficient to show teachers how to operate the machine and review some courseware, it often falls short of including other important topics, such as integrating the microcomputer into instruction.

The *maintenance* condition of our framework leads to the recommendation that staff-development activities be followed up during the period in which the teachers are applying the skills in their classrooms or laboratories (4). Teachers recommended that staff development be ongoing (32)--a multisession (24) initial workshop with follow-up (30). This implies that staff-development activities should be supported by providing enough computers and courseware for "hands-on" practice (28). Moreover, during implementation, teachers need a variety of support services or expert resources to assist with hardware repair, evaluation, selection, and modification of courseware, and day-to-day troubleshooting. At the very least, teacher-networks might be formed to exchange ideas and experiences concerning microcomputer-based instruction (20).

Incentives are recommended for all phases of staff development (workshops and follow up) to support and encourage microcomputer-based instruction (3). However, our results suggest that teachers nominated as successful in microcomputer-based instruction do not participate in staff-development activities because of incentives. One reason was their high level of interest in and commitment to microcomputer-based instruction. Another was that many of these teachers had attained maximum salary levels. A third reason was that such inducements to participate might prompt teachers to participate for the wrong reason.

These findings do not imply the absence of incentives. On the contrary, they suggest that the *types of incentives* offered need to be given careful consideration. Release time and, to a much lesser extent, salary credits were standard incentives for staff development in our study. For many teachers, time was more valuable than money. They had many more ideas about how to use computers than they had time to put them into practice. This suggests that time, rather than monetary rewards, might be the major factor in supporting and encouraging successful microcomputer-based instruction.

Recommendations for the Content of Staff Development

The basic staff-development course probably should include the following topics: operation of the microcomputer (9), selection and evaluation of courseware (11), instructional uses of microcomputers (22), computer literacy (13), and methods for integrating microcomputers with the ongoing curriculum (15). This course might also include computer programming (10), at least to the degree that programming either helps teachers understand how the computer operates, or satisfies the variability condition discussed above.

Operation of the Microcomputer. Instruction in the operation of the microcomputer would include starting the computer, loading and running programs, keyboarding, and minor troubleshooting. The time and effort needed to become a fairly skilled "operator" is on the order of two to six hours.

Selection and Evaluation of Courseware. Teachers should review a wide range of courseware that is appropriate for their grade level and focus on courseware immediately available for their use. This review would include application of evaluation criteria to the wide variety of courseware packages and selection of high-quality courseware based on the evaluation. Courseware evaluation forms might be developed by teachers and district staff with expert consultation, or evaluation guides might be adopted from those designed for microcomputer-based educational software (see Section VI for additional details on courseware evaluation).

Instructional Uses of Microcomputers. Microcomputer-based instruction involves more than just instruction that can be delivered by a program on tape or disk. We recommend exposing teachers to other roles the computer can play, such as a tool for data-analysis or as a tutee to be instructed by students writing or using simple programs (cf. Taylor, 1980).

Computer Literacy. Teachers recommended that initial training include computer "literacy." They sought knowledge about the computer such as the history of its development and issues regarding uses of the computer in society at large. Literacy might also include reviews and evaluations of research on computer-based instruction.

Integration of Computers with Instruction. A critical element of staff development, and one that we saw most lacking in our study, is training on how to integrate microcomputer-based instruction with subject matter and class activities. Simple logistical procedures need to be considered, such as rules for student use, transitions between computer and non-computer activities, and grouping strategies. More importantly, teachers need guidance in how to plan the best utilization of the computer in their instruction. They need sufficient information to begin to make reasonable decisions about matching the computer and available courseware to their instructional goals, the structure of the subject matter, the nature of the students, and the content of instruction. Moreover, they need to acquire interactive teaching skills that will help them carry out their plans, monitor and evaluate instructional activities, and make adjustments when required. These decisions and instructional practices, of course, constitute part of what teachers do every day, whether or not they use a computer. Computers, however, introduce an additional order of complexity to teaching.

Integration involves not only the use of microcomputers as learning activities within the ongoing curriculum; it also involves the adaptation of the curriculum to important software packages (e.g., Logo, "Koala Pad" for drawing). Lesson plans, introductions to the lesson, ways to get students to transfer what they are learning, and methods for monitoring and evaluating microcomputer-based learning activities must be developed sensibly to integrate a new piece of software into the curriculum. Teachers need to be trained to do this as well.[3]

Computer Programming. We recommend that computer programming be included in introductory staff development to the extent that such knowledge is needed to understand how the computer works and to understand the basis for applying the other skills recommended above, such as troubleshooting computer operation. Thus, some programming will be an essential part of training, but perhaps to a much lesser extent than many non-teachers would like.

The depth to which programming is taught in an introductory course will depend, in large part, on the variability condition--the extent to which teachers need to know how to program in order to use the microcomputer instructionally. We suspect that mathematics teachers, both elementary and secondary, will need more extensive introductory training in programming than most others because simple programs can be written as tools for solving mathematics problems. We have excluded, for example, science teachers because we suspect that the more complex data analysis programs or simulations often used are too time consuming for students or teachers to develop as part of the regular science course. However, this decision must, ultimately, be made locally.

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[3] We are indebted to David Berliner for pointing out this aspect of integration to us.

VI. CHARACTERISTICS OF TEACHER-FRIENDLY COURSEWARE

Startling as it may sound, there is almost universal agreement on an important educational issue: the quality of currently available courseware is generally poor, and the extent of curricular coverage highly restricted (Becker, 1982; Chambers and Sprecher, 1983; OTA, 1982). Moreover, most educators and policy analysts agree that high-quality courseware is essential if computers are to make a significant contribution to education (Braun, 1977; Chambers and Bork, 1980; *Electronics*, 1983; Molnar, 1977a,b; OTA, 1982).

Where, then, is the lack of consensus so characteristic of education? It lies in what constitutes "quality." A number of factors account for why the quality issue has not been tackled in a more extensive, systematic way in the past:

- The development of quality courseware is costly and the strength and stability of the educational market uncertain. These factors combine to create financial barriers (Braun, 1977; Molnar, 1977a,b; OTA, 1982).
- Courseware design principles currently used to develop programs for microcomputers are those developed for large machines of the 1960s and early 1970s (Loop and Christensen, 1982). These principles do not necessarily take advantage of the capabilities of microcomputers or of instructional design and cognitive-science research over the past fifteen years.
- The programming languages used (generally BASIC or Assembly) are not conducive to systematic software design and structured design and structured programming methods (see e.g., Sommerville, 1982; Wirth, 1973). This makes it more difficult to write long programs and virtually impossible to modify existing ones.
- Much of the courseware is written by individuals in a courseware-development cottage industry, where few individuals have the combination of subject-matter expertise, software

design principles, and programming skills required to produce non-trivial, high-quality courseware (Becker, 1982). Moreover, some courseware developers often have insufficient contact with students or actual classroom situations for them to write courseware that teachers find "friendly" to use.

- Courseware developers and educators have not been able to communicate with each other. This became quite evident at an NIE-sponsored conference on educational software. Both sides seemed to talk past one another on key issues (*Education Daily*, September 15, 1983, pp. 3-4):

Educators	Courseware Providers
"Too many trivial drill and practice programs"	"Nobody knows what teachers want"
"Too many high cost programs"	"Schools pinch pennies in purchasing courseware"
"Too little opportunity to review programs"	"Schools illegally copy programs"

The purpose of this section, in broad terms, is to begin to bridge the communication gaps between educators and courseware providers by setting forth recommendations regarding the attributes of quality courseware. We collected "successful" microcomputer-using teachers' recommendations for quality courseware, examined whether these recommendations varied according to differences in the patterns of their microcomputer-based instruction, and integrated these findings with the literature on courseware and its development to reach our recommendations. More specifically, we set forth recommendations for improving the quality of courseware based on reviews of courseware types (Appendix C), courseware development strategies and evaluation guides, "successful" teachers' evaluations of available courseware, and our experience with courseware and other types of educational software.

COURSEWARE LITERATURE

Courseware Development Methods

The process of courseware development can directly affect courseware quality. The prevalence of low-quality, drill-and-practice courseware may be due, in large part, to the fact that the predominant method for developing microcomputer-based courseware has been individual *authoring*, in contrast to systematic *design* which generally involves a development team (Bork, 1984; Chambers and Sprecher, 1983; Roblyer, 1981).

Our rationale for these assertions is the following. Courseware authoring is generally done by individuals in their spare time. Consequently, programs tend to be short, simple, and require minimal production time. For this reason, and because many individual courseware projects are seen as "one-shot" efforts, individual authors rarely develop a systematic and easily portable set of tools or utilities for use in multiple programs. Such utilities are essential to quality courseware; they include the means for making a program "crash-proof," and procedures for presenting text or graphics, or for handling various types of student and teacher input. Rather than investing a considerable amount of time to develop such tools, authors often avoid the issue by writing programs that involve only simple student input and that often are not crash-proof.

In an individual authoring process, content and pedagogy are often formulated *during* the writing process. The result is a program that works well, but that lacks coherent overall design. Such a program is very difficult to revise; a new program of similar quality is usually easier to write. Only relatively short programs can more easily be rewritten than revised, however. This is one reason why individual authoring is ill-suited for producing courseware intended to help teach substantial portions of a course or to teach a topic in a sophisticated and adaptive manner. This is especially true for courseware that goes beyond simple drill and practice, and involves complex input analysis, decisions, and branching.

The alternative to individual authoring is a courseware design strategy (Roblyer, 1981; see also, Chambers and Sprecher, 1983), or a production system (Bork, 1984). This is a multiphase, multiperson process. The development process takes place in several phases, including design, development, evaluation, and revision. Each of these includes subtasks, such as specification of learning goals, design of learning materials, specification of presentation format and screen layout, and coding. Each phase involves one or more individuals with expertise appropriate to the demands of the task. This selective use of experts for each task is a key element in design strategies.

Multiple rounds of evaluation and revision are integral to design strategies. Such evaluation involves in-house review, as well as testing the materials with individuals from the intended audience. Revisions and corrections are made on the basis of these formative evaluations. This cycle may include other steps, and may be repeated as often as deemed advisable.

Evaluation and revision are essential to the creation of high-quality courseware. Authoring and design methods differ greatly in their provisions for evaluation and revision. Individuals often lack systematic and sufficient access to the intended audience. This makes an adequate test of the materials less feasible, and hence less likely. Moreover, even if they were tested, revising some programs might be a hopelessly formidable task. Because of the importance of evaluations and subsequent modifications in the development of any learning materials, we derive our first recommendations from the design strategy for evaluation cycles.

RECOMMENDATION 1: Build evaluation and revision cycles into the development process, and have programmers in design teams code materials with the prospect of revising in mind.

RECOMMENDATION 2: Make one of the first tasks for a design team the development of utility software to facilitate various aspects of the development process.

Software utilities should include capabilities for presenting text and graphics on the screen, allowing a variety of inputs by the student, making programs crash-proof by disabling keys inappropriate for a given input, facilitating input analysis, and allowing the storage of user input for evaluation purposes. Clearly, this will be an expensive task; however, if done properly, the utilities will be useful for developing all subsequent courseware and also for simplifying the transport of courseware from one computer to another (by isolating procedures that involve machine-dependent code). The cost for the utilities will thus be a one-time investment.

Initially, courseware designed and created by a team will be more expensive than individually authored courseware. These costs must be borne however, since the amount, scope, and sophistication of courseware that will be needed in the next decades (Molnar, 1977a,b) can only be created in a manner that:

1) allows the development of large, but easily revisable, programs;
2) includes quality control (i.e., evaluation) facilities; and
3) meets the curricular requirements set by school boards and teachers.

Courseware Evaluation

Developers must evaluate courseware to ensure that it is free of errors--factual, linguistic, and programming. The teacher or someone familiar with the school's students and curriculum must also evaluate it, to ensure that the courseware fits instructional goals, and is appropriate for the intended audience.

Proper evaluation of a program requires several cycles of evaluation (see Recommendation 1) by teachers (and developers), each conducted from different perspectives. Very generally, one session in the evaluation cycle should be carried out from the teacher's point of view. Is the material suitable for the instructional goals of the class? Does the program fit the teaching approach in the class? Could the experience gained at the computer have been acquired as well with less expensive means? Other sessions should be conducted from the perspectives of several types of students (e.g., one who answers everything correctly, one with difficulties, and one who inputs inappropriate answers to questions). If evaluators find something unacceptable during any of these sessions, they may decide to reject the program immediately (see, e.g., Lathrop, 1982c, for such characteristics).

We formulated courseware recommendations for evaluation in terms of cycles since these cycles are pertinent to both teachers and developers (see Alesandrini, 1983; Kansky et al., 1981):

RECOMMENDATION 3a: In evaluating courseware, the first "student session" should include only correct answers, to test the correctness of the program content.

RECOMMENDATION 3b: In evaluating courseware, the next "student session" should include numerous incorrect answers, to determine the diagnostic capabilities of the program, as well as the feedback and help available to the student.

RECOMMENDATION 3c: In evaluating courseware, a third session should include inappropriate input and attempts to crash the program or otherwise set it "off track," to see whether it recovers gracefully from unexpected inputs.

RECOMMENDATION 3d: In evaluating courseware, if possible, students should be observed using the program.

For the purpose of evaluating courseware, published evaluation guides can be particularly helpful in serving several functions (e.g., MicroSIFT (1981), the National Council of Teachers of Mathematics, or the NCTM (Heck et al., 1981; see also Kansky et al., 1981; see Dennis, 1979c; EPIE, 1983; Lathrop, 1982b; Lathrop and Goodson, 1983, for additional information about evaluation sources). First, they help the teacher form a systematic impression of the courseware. Second, they help teachers clarify for themselves what they expect of the courseware and perhaps even what considerations should underlie their evaluations. Third, they provide a common language for discussing courseware quality. Finally, completed evaluations can be filed in an accessible library of reviews. Teachers considering a program may find out about it through such libraries--either to supplement their own evaluation or as the primary source of information if they could not preview it.

Evaluation guides also provide useful information to developers, because a carefully completed guide indicates clearly the criteria and priorities educators consider when looking at courseware. Despite the obvious utility of such evaluations as a source of information for both teachers and developers, and as a means of communication between these two groups, most evaluations tend not to be communicated; open channels do not currently exist. The reviews that do appear in journals cannot begin to cover adequately all the courseware available or soon to appear.

At various points in the interviews, teachers in our study complained about the lack of opportunity to thoroughly review and evaluate courseware before deciding whether to purchase it. In some cases, this lack of opportunity was due to publishers' restrictions; in others, it was the result of district or school courseware purchasing methods. Despite the recognized importance of evaluation, very few teachers in our study reported using a systematic and elaborate set of evaluation criteria when examining courseware; almost none used any of the published evaluation guides.

To provide some perspective on considerations for evaluating courseware and on teachers' recommendations in the next section, we briefly discuss some evaluation guides that have attained relative prominence. Several general points deserve mention. First, the criteria found in these guides are notable more for their range and variety than for their overlap, as is the case with the teachers' responses summarized below. Second, although the guides are ultimately checklists, the good ones cannot be completed quickly.

As is the case with evaluation guides in general, the three published guidelines considered here--the California Library Media Consortium for Classroom Evaluation of Microcomputer Courseware (Lathrop, 1982a), the Evaluator's Guide for Microcomputer-Based Instructional Packages (MicroSIFT, 1981), and the NCTM's Guidelines for Evaluating Computerized Instructional Materials (Heck et al., 1981)--are not easily compared. Particular questions or issues appear in different contexts and receive differential elaboration in the guidelines. We mention the common points, and also noteworthy items found only in one or two guides.

All three guides include items for systematically describing the courseware: name of program, type of program, hardware required, audience, subject area, intended audience and use (e.g., individual or group). Two guides include an item for prerequisites. This information is important to a teacher trying to determine whether students will profit from the materials.

RECOMMENDATION 4: Developers should provide explicit information about the type of program, hardware required, audience, subject area, intended audience, and skills the student is expected to have in order to use the courseware.

All three checklists have at least one item on the accuracy and the instructional value of the content. Other points include the match between the level of the material and the audience, and the compatibility of the program content with other materials used in the course. The nature of student activity in the program is assessed by items about: the degree of student activity, the extent to which creativity is encouraged, and several motivational effects of the material. Related to these are items concerning user control over program aspects, such as speed and sequence.

Technical aspects and the friendliness of the programs are assessed by items concerning the clarity and detail of instructions and the ease of use without supervision. Quality of the output--e.g., nature of feedback--is also included. Lathrop (1982c) included the following as necessary for courseware to be worth considering.

RECOMMENDATION 5: The program should never make derogatory comments about student errors or respond audibly to a student error.

RECOMMENDATION 6: Screen layout should not be cluttered by, for example, crowded text material; rather, it should be spaced so as to facilitate the student's visual scan of the information.

The capabilities and requirements of the hardware may also be included in these checklists, either as an item asking about the extent to which the computer is being used to its full potential or as a set of items concerning specific computer facilities such as color or sound. Finally, the program's *robustness* (freedom from errors) is a consideration in each of the checklists.

Other evaluative criteria include items based on students' (as opposed to teachers') reactions to the program (Lathrop, 1982a), and items concerning social topics, such as moral issues or value judgments in the program (Heck et al., 1981). The MicroSIFT (1981) form includes a column for indicating the importance of a particular item or criterion for the rater. Finally, an EPIE and Consumer's Union PRO/FILE has an especially valuable feature: "Recommendations to the Producer," which contains explicit comments and suggestions for the courseware producer.

Access to Courseware for Review

Systematic and equitable means for providing teachers with information about courseware, and developers with feedback about the reception of their materials, are needed. Teachers must either have direct access to the courseware (in order to review it themselves), or to extensive and objective reviews by other teachers. On the other hand, developers must have some assurance that their copyrighted products will not be used without authorization.

Courseware libraries, readily accessible to teachers (perhaps by telecommunication) that contain programs with evaluations can serve this end. They could be an excellent resource for teachers. They also offer a means of evaluating courseware without threatening publishers' property rights through copy restriction violations. By making the programs available for evaluation to such libraries, publishers will provide teachers with at least indirect information about the programs. Because it provides teachers with essential information, without compromising publishers' rights to their product, some evaluation procedure that will achieve these ends can justifiably be expected of any publisher who wishes to sell courseware to schools.

TEACHERS' COURSEWARE RECOMMENDATIONS

Recommendations for improving courseware were examined according to patterns of microcomputer-based instruction with the expectation that the recommendations of teachers in the orchestration cluster might prove to be quite insightful. This is because they, on average, used more different types of courseware and were rated higher on breadth and depth of their courseware knowledge than teachers in the other clusters. These differences were especially pronounced when these teachers were compared with teachers in the drill and practice cluster on their use of tutorials, simulations, and microworlds.

In order to gather data on teachers' courseware recommendations, we asked them four questions during the interviews: (1) Do you, your school, or district have standard criteria for evaluating courseware and, if so, what are they? (2) What features do you look for in selecting courseware? (3) What features do you try to avoid? And (4) How could courseware be improved, based on your experience? Teachers' responses to these open-ended questions were content analyzed by grouping responses into meaningful categories. Since respondents did not have probes to "jog their memories," they may have forgotten to mention something important. And, some respondents had much more to say than others. Hence, 40 percent of the recommendations came from 25 percent of the respondents; overall, the average was 5.39 recommendations per respondent. For this reason, we focus not so much on numbers of teachers making a particular recommendation but on whether teachers in a cluster made the recommendation. In the end, we sought breadth in identifying positive and negative courseware attributes, and in creative ideas for improving courseware, rather than on wholesale agreement on recommendations. However, note that, in general, these "successful" teachers had not given a great deal of thought to desirable courseware attributes.

Recommendations and admonitions of teachers in the four clusters are presented in Tables 6.1 through 6.5. By and large, there were few discernible differences among the clusters, with two exceptions. Teachers in the orchestration cluster differed systematically from teachers in the other three clusters only in the number of recommendations, averaging about 6.7 recommendations. The teachers in the enrichment cluster seemed to be more concerned about courseware acquisition than teachers in the other clusters.

Very broadly, teachers' responses concerned the following courseware attributes: general *friendliness* of a program such as the clarity of its instructions or the ease of its operations, and the friendliness for the teacher's purposes such as whether the teacher can modify it; *courseware content* such as the coordination of its topics with a particular curriculum; *pedagogy* such as requiring critical thinking on the student's part; *computer use* such as the extent to which the courseware fully uses hardware capabilities (e.g., graphics); and issues relating to the *selection* and *acquisition* of courseware.

Friendliness

An essential attribute of a satisfactory instructional program is that it not stop ("crash") upon inappropriate input. Teachers in all four groups felt that courseware needed to be made "crash-proof" and sufficiently "bug" free to allow normal operation (see Table 6.1).

Table 6.1

FRIENDLINESS OF COURSEWARE

	Cluster				
Item[a]	1	2	3	4	All
General Friendliness					
(7) Crash-proof	5	2	1	2	10
(8) Easy to use	4	5	0	1	10
(9) Clear and appropriate instructions	4	4	6	0	14
(10) Self-contained instructions; usable without teacher supervision	2	1	1	1	5
(11) Accompanied by comprehensible documentation	3	3	1	0	7
(12) Uses consistent student input format	0	3	1	0	4
(13) Graceful entry to/exit from program	1	2	1	0	4
Friendliness for Teacher					
(14) Can be modified by teacher	5	2	1	0	8
(15) Number and type of problems can be varied	1	3	2	0	6
(16) Keeps track of student progress (CMI)	3	6	2	2	13
(17) Instruction options	3	0	1	0	4
(18) Personalization possibilities	3	0	0	0	3
(19) Can be networked	0	3	1	0	4

[a] Numbers in front of each recommendation refer to recommendation number.

On the whole, the recommendations regarding courseware friendliness tended to come from teachers in the first three clusters. Teachers felt courseware had to be "friendly." Forty-three percent of the respondents (coming from all four groups) mentioned details relating to the program's friendliness and ease of use--including clarity and simplicity of instructions, on-line instructions, and the inclusion of clear and adequate documentation. Teachers recommended that courseware should be capable of running without their supervision, and that it should consistently require the same input from the student. The manner in which the student begins and ends an interaction with the program was also mentioned in relation to courseware friendliness. Teachers felt, for example, that programs should not end abruptly.

A second set of courseware-friendliness attributes pertains to the teacher's option to modify it to fit more closely with the curriculum or their students' needs. Most generally, these capabilities concern the possibility of customizing courseware for specific purposes or situations. Members of several groups wanted courseware that could be modified for particular needs, such as varying the number or type of problems, the specific information in the program, or the length of a session. Other modification capabilities included the possibility of skipping instructions, personalizing an interaction, and networking. Members of all groups said they wanted some sort of record-keeping or management facility in the courseware.

Content

An essential requirement for an instructional program is that the material be free of content, grammatical, and spelling errors (see Table 6.2). Only members from group 1 explicitly said they checked that courseware was free of such errors. Similarly, members of three groups mentioned that courseware should have substance, and should not simply present trivial examples of the material. Several teachers, all from groups 1 or 4, considered it necessary to mention that a program should do what developers claim it does. Finally, teachers in all four groups recommended that courseware be coordinated with particular curricula or texts. Only teachers in the orchestration cluster were represented in all recommendations pertaining to content.

Table 6.2

COURSEWARE CONTENT

Item[a]	Cluster 1	2	3	4	All
(20) Free of content errors	3	0	0	0	3
(21) Free of grammatical and spelling errors	1	0	0	0	1
(22) Well-grounded in subject matter (i.e., non-trivial content)	2	2	4	0	8
(23) Teaches content it claims to teach	6	0	0	1	7
(24) Coordinated with texts and other curricula	2	2	5	3	12

[a] Numbers in front of each recommendation refer to recommendation number.

Pedagogy

With regard to factors that might affect students' learning experiences with the courseware, members of three groups recommended that the learner be active throughout the program (see Table 6.3). Our respondents said courseware should be written at a pace and level appropriate for the intended students' abilities and that the materials should have multiple levels for students differing in ability. One teacher explicitly mentioned that the vocabulary in an instructional program must also be appropriate for the audience. Also recommended was the development of courseware usable with students in groups. Several teachers mentioned that courseware should be entertaining or humorous.

Teachers had numerous suggestions relating to the pedagogical strategies, goals, and specifications underlying courseware. Members of all clusters felt courseware should emphasize critical thinking and problem solving skills. Details mentioned in this regard included having the student make decisions based on the material; apply content in new situations, or formulate hypotheses; and making the material constantly challenging for the student. Members from three of the groups said they expected courseware to be capable of sophisticated error analysis and diagnostics, and of providing detailed and relevant

Table 6.3

PEDAGOGY OF COURSEWARE

Item[a]	Cluster 1	2	3	4	All
(25) General interaction	0	1	0	0	1
(26) Active involvement of student	2	2	1	0	5
(27) Pace appropriate for student	1	0	1	0	2
(28) Appropriate difficulty level for student	1	4	4	0	9
(29) Multiple difficulty levels available	2	1	0	1	4
(30) Mode of instruction appropriate for subject matter	0	1	0	0	1
(31) Possible use with groups of students	0	0	1	0	1
(32) Entertaining and fun to use	4	3	0	0	7
(33) Teaches thinking and problem solving	3	2	1	1	7
(34) Branching instructions based on student performance	0	3	1	0	4
(35) Capable of sophisticated diagnostics and detailed feedback	0	3	2	1	6
(36) More courseware in particular mode	3	2	1	0	6
(37) More courseware in specific subject	1	4	1	0	6
(38) Involve teachers in design	4	2	4	1	11

[a] Numbers in front of each recommendation refer to recommendation number.

feedback concerning an answer. One teacher mentioned that the courseware mode (i.e., drill and practice, simulation) should be appropriate to the subject matter. The match between instructional style and subject matter is rarely discussed explicitly in relation to courseware.

Teachers also had specific requests for more courseware in particular modes, in particular subject areas, or for particular grade levels. There was a variety of suggestions here, and these responses are perhaps best seen as indicative of the range of interest in using computer materials. This should encourage developers, because it suggests a waiting market for quality courseware.

Members of all clusters felt teachers should play a more active role in the design and development of courseware; however, as with content issues, teachers in the drill and practice cluster were least likely to make a particular recommendation regarding pedagogical aspects of courseware.

Uses of the Computer

Members of all groups said they expected courseware to use graphics (see Table 6.4). Various respondents also mentioned other modalities (e.g., sound and color). Nevertheless, teachers did not support the uncritical use of these facilities; rather, they felt these should be used in moderation as appropriate. Members of all four clusters expected a program to make full use of the computer's capabilities--i.e., to go beyond a mere electronic workbook. Respondents in all groups considered an arcade or game format desirable. (See the discussion of intrinsic models in the section on Instructional Games in Appendix C for additional recommendations in this regard.) All groups were concerned that the computer's capabilities be used fully and effectively.

Table 6.4

MICROCOMPUTER USES OF COURSEWARE

	Cluster				
Item[a]	1	2	3	4	All
(39) Uses graphics	6	3	2	1	12
(40) Uses full capabilities of computer	1	1	2	1	5
(41) Uses arcade or game format	1	4	3	1	9

[a] Numbers in front of each recommendation refer to recommendation number.

Selecting and Acquiring Courseware

With respect to issues related to courseware selection and acquisition (see Table 6.5), teachers--especially those in the enrichment cluster--commented on the expense of courseware, expressed a desire to evaluate courseware more extensively before buying it, and wanted more liberal rules for making backup copies of the courseware and for its use (e.g., for networked configurations). Similarly, a teacher mentioned that courseware should have strong guarantees that it is not defective. One teacher suggested that students be given a greater opportunity to evaluate courseware prior to selection.

RECOMMENDATIONS FOR COURSEWARE DEVELOPMENT

By considering characteristics of different types of courseware (Appendix C), evaluation criteria and guidelines, and information from interviews with teachers, recommendations were derived for courseware design and development. Here we briefly summarize these recommendations. Many of the recommendations already influence courseware development; we mention them to reinforce them, to gather them in one place, and to consider them within the teaching context. As we will see, most of the recommendations can be addressed within the framework of group-based courseware design strategies. Numbers in

Table 6.5

SELECTION AND ACQUISITION OF COURSEWARE

Item[a]	Cluster 1	Cluster 2	Cluster 3	Cluster 4	All
(42) Less expensive courseware	0	2	0	0	2
(43) Greater preview possibilities	0	2	0	0	2
(44) Greater opportunity to make backups	0	1	0	1	2
(45) Better guarantees (stronger sanctions) against defects	0	1	0	0	1
(46) More student evaluation before sale	0	0	1	0	1

[a] Numbers in front of each recommendation refer to recommendation number.

parentheses refer to recommendations identified above. Recommendations derived in Appendix C are included here, and are prefixed with a "C."

Rules and Skills

The consideration that instructional rules for playing games should be simpler than the skills being taught may be generalized to the recommendation that courseware instructions be sufficiently simple and unobtrusive that they do not distract from the pedagogical goals of the program (C1). This is achieved by acting on recommendations relating to courseware friendliness (7-13). Similarly, recommending intrinsic models on motivational grounds (C2) generalizes to suggesting that the activities involved in a pedagogical task bear directly on the understanding being gained. The skill with which this is carried out will depend on the creativity of the designers.

The Role of Teachers in Courseware Design

Several recommendations can be dealt with by including teachers or subject-matter experts in the design process (38). Certain aspects of documentation and development of ancillary materials are best done by persons directly involved with the subject matter and the audience. These include writing materials for, say, simulations that will guide active inquiry and examination of the phenomena, while leaving students in control of details of the learning (C4). Similarly, teachers will best know the prerequisite skills required to master course content (4); they, rather than the programmer, should determine and communicate the prerequisites for a program. Including teachers in courseware design will also help assure that the content is non-trivial (22) and free of errors (20, 21), that the level, pace, and mode are appropriate for the intended audience (27-30), and that the program actively involves the student in the learning process (25, 26). Teachers can also influence the mode (e.g., tutorial, simulation) and subject area (36, 37) of the courseware.

Involving teachers in the design also makes it more likely that critical thinking and problem solving skills will be emphasized (33). Knowledgeable teachers are aware of common misconceptions held by students and the best didactic paths for correcting them. Teachers will thus help assure that programs have the diagnostic and feedback capabilities desired (34, 35). Teachers are also familiar with the curriculum, and with popular textbooks; the teachers on the design team can coordinate the courseware with other materials (24).

Because they are most familiar with the particular demands of courses in the subject area, teachers will make the best consultants on how other teachers may want to modify courseware (14, 15), or customize a data base (C6); they will also have ideas about computer uses in group or laboratory settings (31). Teachers can contribute to the type of interaction required at a given point in a lesson; programmers can decide how to accomplish this in a program. Finally, teachers may provide useful judgments as to whether a program fulfills the pedagogical goals set for it before it is evaluated empirically.

Evaluation--Revision Cycles

The continued evaluation and modification of courseware (1) until it satisfies criteria set for it allows developers to deal with several recommendations. The opportunity to examine a program several times helps to determine what information about students' interactions with the material will be most useful for that program, and makes it possible to build these into record keeping facilities (16). Similarly, testing a program in several ways (e.g., 3a-3d) makes it more likely that major "bugs" will be found. As the program becomes more error free (robust), developers can concentrate on refining the potential crash spots (7). This helps ensure that all instructions at those and other points in the program are clear, and that any difficulties are dealt with gracefully rather than cryptically (13). Since these stringent and repetitive evaluation strategies will result in higher-quality, more robust programs, they will allow the developer to make stronger guarantees against defects (45).

Much of the information helpful for making the program friendlier will also be uncovered during these cycles, although much of it will presumably be built into the original design. By observing the courseware in use, developers will be able to determine where instructions or documentation are unclear (11), and to modify the program until its built-in instructions allow students to use it without supervision (8-13). Finally, the more often a program is examined, the more likely that any grammatical or spelling errors will be corrected (21).

Design Strategies

Both the use of teachers and the provision for multiple revision cycles are part of design or production systems (C3); furthermore, these systems include experts in the technical aspects of the development process. As mentioned above, one of the first tasks when forming such a production system should be to develop a set of utilities (2). These make subsequent coding and maintenance tasks much easier. In addition to helping make the program crash-proof, such utilities are essential in making effective and pleasant screen layouts (6) possible at reasonable costs. Software design and engineering methods are essential for long programs, such as those required to cover substantial parts of the K-12 curriculum.

Technical experts are best able to inform teachers about the possible uses for courseware like Logo (C5), although cooperation with teachers will be needed to identify those uses that would be most effective for class use. Coders are best able to ensure that computer capabilities are used effectively (39, 40), although again in conjunction with subject-matter experts who can help determine what these uses should be, and when particular facilities are most appropriate.

Thus, the use of a design strategy involving educators, programmers, and other experts emerges as the unifying recommendation for the great majority of the implications and suggestions discussed in this section. Because it uses a variety of expertise as needed, the strategy allows complex specifications and recommendations to be carried out.

Reviewing and Copying

Recommendations for reviewing and copying courseware may be more difficult than other recommendations to implement in a universally satisfactory manner. Nevertheless, establishing libraries where teachers can examine potential courseware can help make the materials more available for inspection (43, 46), while protecting the interests of the publisher (44). This will help lower the price of courseware (42). Nevertheless, the cost of quality courseware--at least initially--will reflect the great risks and costs associated with courseware development.

The use of development teams and production systems is an effective way of creating sophisticated courseware--because it utilizes the various talents of several people. It is, however, expensive (Bork, 1983; Braun, 1977; Molnar, 1977a,b). Estimates for the cost of one hour of highly interactive tutorial material are in the $5,000-$10,000 range.

Ultimately we believe that the use of design teams encompasses the inclusion of teachers, subject-matter experts, instructional-design experts, and programmers in the development process; a multiple cycle process of evaluation and revision is also essential. By using design strategies, courseware developers will be able to act on the recommendations summarized here, and will be able to develop courseware that takes full advantage of the technical and pedagogical possibilities of personal computers.

A Courseware Scenario

We conclude with a brief sketch of hypothetical courseware that incorporates many of the recommendations summarized here. The program is a tutorial dialogue, with a clearly defined and well-documented set of prerequisite skills demonstrating that the dialogue content is appropriate for the learning audience. The documentation is written clearly, providing insights into the topic area and the program task to both teacher and students. It refers students--those having difficulties, but also those desiring further challenge--to other materials or to the teacher.

The student is continually active in using the program and must provide a variety of inputs to the program. When appropriate in the instructional sequence, the program simulates an experiment or creates a microworld for the student to explore. (The use of simulation and microworlds in a tutorial dialogue indicates that high-quality courseware transcends simple courseware classification typologies.) If the student has difficulties (e.g., does not respond within a specified amount of time), the program prompts for the next response, provides a hint, or asks whether the student knows how to proceed. This decision, made by the program, is based on a model constructed by the program of the student's knowledge base. The program continually checks its diagnostic accuracy on the basis of the student's subsequent responses and alters its model of the student's knowledge accordingly.

The tutorial dialogue does not replace the teacher. Rather, it acts as part of the teacher's repertoire, freeing the teacher for other tasks such as tutoring other students who need assistance. This is possible because the program is crash-proof and friendly enough that students can use it independently or in small groups without a teacher's constant supervision. In this way, a group teaching context can be turned into individualized lessons, where each student or group of students receives as much computer-based and teacher-based instruction as needed.

APPENDIX A:
INSTRUMENTATION

Revised 2/9/83

DISTRICT ADMINISTRATOR INTERVIEW GUIDE

Instructions to Interviewer: Briefly explain that the purpose of this interview is to gather information about the organizational environment for instructional use of microcomputers in the district such as how the district first decided to implement microcomputers, what steps were taken to get things going, what they're doing to support microcomputers for instruction, and the kinds of changes that have occurred.

Although we will focus on certain questions, we are interested in any other information the respondent feels will help us understand the organizational structure in the district that has been established for using microcomputers, and the process for implementing computers, including future plans.

Assure the respondent that his or her responses will remain anonymous. No one else in the district or school will have access to them, nor will anyone else who is not directly associated with the research study. In addition, school districts will have pseudonyms in any written reports.

If, after the interview, the respondent thinks of other information which will help us, he or she may call or write to us at Rand.

After the interview, collect any relevant documents available, such as policy about computers, curriculum specification, agenda and materials used for staff development.

District Administrator Interview Guide

District Name: ______________________________

Respondent's Title: __________________________

First, I'd like to talk about how and why the microcomputer came to be used for instruction in this district.

1. How did microcomputers come to be used for instruction in this district?

   Probe--whether primary came from top down (administrative decision), bottom up (grass-roots), or combination

2a Who supported the introduction of microcomputers in this district? What reasons did they give for supporting computers? (names are not necessary; just tell me their role, e.g., teachers, parents, school board.)

2b. Has there been any resistance to the introduction of microcomputers? What kinds of concerns have been expressed? (e.g., lack of funds, lack of interest).

The next question focuses on the ways microcomputers were implemented in this district--how specific decisions were made--on equipment, training teachers or other personnel, and so on.

3. As microcomputers were implemented in this district, who had primary responsibility for decisionmaking in the following areas: (No names necessary, just the position of persons involved.)

Equipment

Software

Staff development/teacher training

Physical Arrangement

Let me ask you now about current district policies toward computers.

4a. Does the district have a formal, written policy toward computers?

_____ YES: (Obtain copy of statement if possible.)

_____ NO

4b. At present, what are the district's major goals for using microcomputers in instruction? Is there a general strategy for introducing computers into the district?

4c. How much progress have you made in reaching these goals?

I'd like to ask about support and training provided for teachers that use computers in this district.

5. Are technical assistance or material resources routinely provided by the district? (e.g., programmer, curriculum specialist.) Describe:

6. Is the district providing any staff development or training about microcomputers?

Yes, has provided	☐	ASK a, b, & c and question 7
Not yet provided but planned	☐	ASK a, b, & c, then skip to 8.
No, none provided or planned	☐	SKIP TO Question 8

(a) What kinds of staff development were/are/will be provided?

(Probe for specific information about organization of training and what topics were covered).

(b) Are all staff trained the same way, or does training differ for different personnel (administrators, teachers grade level or subject matter).

(c) How many hours of training does each teacher get, on average? __________ hours

7. Please evaluate the training provided by the district.

How satisfied are you with the training provided by district? What features were you especially satisfied or dissatisfied with?

Now I have a few questions about district funding for microcomputers use in instruction.

8. (a) Are computer-related services, equipment, software, and the like currently a line-item in the district budget?

_____ YES

_____ NO

(b) What (other) budget categories provide funds that are used for computer-related purposes? (Probe for how hardware, software, and any training/support are funded.)

(c) Does the district have or rely on other outside sources of funds for computer-related purposes (PTA, parent fund raising, state grants, etc.).

(d) Do the sources of funding limit or constrain the use of the computers in any special way (e.g., only gifted or disadvantaged students could use the computers).

9. Now I'd like to ask about some of the ways in which microcomputers are used for instruction in this district.

   (a) How many microcomputers are there in the district?

   (b) How many microcomputers are located in teachers' classrooms as opposed to lab arrangements and location? Describe arrangements and location

   (c) What subject matter areas are microcomputers being used in?

   Probe--elementary and secondary subject matter areas where applicable)

(d) What kinds of educational programs are being run on the microcomputer? (Probe modes of use; i.e., drill and practice; tutorials)

(e) How well integrated are microcomputer activities with regular, ongoing instruction?

10. I'd like to ask about any changes that may have taken place since microcomputers came to this district/school?

(a) Have any new personnel been hired specifically for their expertise with computers or with computer-based education?

(b) Have there been any official changes in job titles or pay levels for computer-using teachers?

(c) How much, in your judgment, have microcomputers affected the way teachers teach? The way students learn?

11. Finally, I'd like to ask for some of your recommendations regarding instructional uses of microcomputers

(a) What recommendations would you make about the organization and content of teacher training for microcomputers in instruction?

Probe--features of the optimal inservice program (location, length, teacher incentives) and training topics

(b) Based on your experiences with microcomputers in instruction, what recommendations can you make on how courseware could be improved to be more useful to teachers and students?

(c) In general, is there any advice you would give for getting districts and teachers more involved with microcomputers?

Revised 2/9/83

SITE SURVEY INSTRUMENT: DISTRICT ADMINISTRATOR INTERVIEW

School District Name__________________________________Coder__________________

Respondent's Title (Circle one):

a. Superintendent	1
b. Assistant Superintendent	2
c. District Curriculum Coordinator	3
d. Other:__________________________________	9

Knowledgeability of the respondent on administrative matters (1=Not knowledgeable; 4=Extremely knowledgeable)	1	2	3	4
Knowledgeability of the respondent on instructional uses of computers (1=Not knowledgeable; 4=Extremely knowledgeable)	1	2	3	4

1. How microcomputers came to be used for instruction in the district (Circle one):

a. Administrative decision	1
b. Combination of administrative and grass-roots	2
c. Grass roots or bottom-up from teachers	3
d. Other____	9

Describe:

2. Support and Resistance to the Introduction of Microcomputers

To what degree did each of the following support or resist the implementation of microcomputers? (1=Resisted strongly; 2=resisted somewhat; 3=neutral or mixed; 4=supported somewhat; 5=supported strongly; 9=No information)

a. School Board	1	2	3	4	5	9
b. Superintendent	1	2	3	4	5	9
c. Curriculum Supervisor(s)	1	2	3	4	5	9
d. Principals	1	2	3	4	5	9
e. Teacher(s)	1	2	3	4	5	9
f. Parents	1	2	3	4	5	9
g. Other(s)________________________	1	2	3	4	5	9

What reasons were given for supporting computer use?

What kinds of concerns were expressed?

3. Decisions on equipment, software, staff development, and physical arrangement

For each of the following areas, who had primary responsibility for decision-making: (1=District administration; 2=School administration; 3=Individual teachers; 8=Other (describe); 9=No information or not applicable)

a. Computer equipment IF OTHER, identify:	1	2	3	8	9

b. Educational software 1 2 3 8 9
IF OTHER, identify:

c. Staff development/teacher training 1 2 3 8 9
IF OTHER, identify:

d. Physical arrangement of computers 1 2 3 8 9
IF OTHER, describe:

4. District Policies, Goals, and Strategies

a. Does the district have a formal, written policy toward computers? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, Note whether a written policy was obtained: Yes No

b. How important for the district are the following goals for using microcomputers in instruction? (1=Not important; 2=minor importance; 3=major importance; 9=No information regarding goal)

1. Mastery of basic skills (i.e, arithmetic; reading) 1 2 3 9
2. Acquisition of higher cognitive skills (i.e., mastery of concepts or problem-solving procedures) 1 2 3 9
3. Motivation (e.g., positive subject-matter attitudes) 1 2 3 9
4. Classroom management (i.e., orderly work environment; student cooperation or teamwork) 1 2 3 9
5. Computer literacy or enrichment 1 2 3 9
6. Administrative efficiency (including CMI) 1 2 3 9
7. Serve special students 1 2 3 9
8. Other(s)____ 1 2 3 9
____

IF SERVING SPECIAL STUDENTS IS A GOAL; note which (e.g., gifted, handicapped, Chpater I/low achievers, etc.):

c. How much progress has the district made in reaching these goals, according to the respondent? (1=No Progress; 4=Great Progress; 9=Not applicable) 1 2 3 4 9

5. According to the respondent, are technical assistance or expert resources in support of microcomputer use routinely provided by the district? (1=Yes; 2=No; 9=Not applicable) 1 2 9

What technical assistance or expert resources are provided?

6. Staff development/teacher training

Is the district providing staff development or training about microcomputers? (Circle one)

1. Not provided or planned	1
2. Not yet provided but planned	2
3. Yes, has or is providing	3

a. IF PROVIDED OR PLANNED, Describe the organization of staff development:

IF PROVIDED OR PLANNED, List the topics covered/to be covered:

b. Are all staff trained in the same way? (1=Yes; 2=No; 9=No training planned or provided) 1 2 9

IF NO, describe variation:

c. Number of hours of training, on average, per teacher: (Code 999 if no training or don't know) ______

7. Satisfaction with district staff development/training

How satisfied is the respondent with district staff development/training? (1=not satisfied; 4=extremely satisfied; 9=No training provided or not applicable) 1 2 3 4 9

List features that were especially satisfactory:

List features that were not especially satisfactory:

8. District funding for microcomputer use in instruction

a. Are computer-related services, equipment, software, etc. a line item in the district budget?
(1=Yes; 2=No; 9=No information) 1 2 9

b. How many budget categories, other than any earmarked directly for computers, provide funds related to computers?
(Code 99 if no information or not applicable; code 0 if none) ______

IF OTHER BUDGET CATEGORIES PROVIDE FUNDS, Describe:

c. Do outside sources of funding (e.g., national or state grants, private donors) provide funds that can be used for computer related purposes? (1=Yes; 2=No; 9=No information) 1 2 9

IF YES, Describe funding sources:

d. Do sources of funding limit or constrain computer use?
(1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, Describe:

9. Use of Microcomputers for Instruction in the District

a. How many microcomputers in the district? (999=Don't Know) ____________

b. How many microcomputers are located in teachers' classrooms? (999=Don't Know) ____________

Describe location and arrangement of microcomputers in the district:

c. Are computers used in the following subject-matter areas? (1=Used; 2=Not used; 9=Not applicable or no information)

1. Elementary school mathematics	1	2	9
2. Secondary school mathematics	1	2	9
3. Elementary school science	1	2	9
4. Secondary school science	1	2	9
a. Biology	1	2	9
b. Chemistry	1	2	9
c. Physics	1	2	9
d. Other(s)________________________________	1	2	9
5. English (language arts)	1	2	9
6. Foreign Languages	1	2	9
7. Social studies	1	2	9
8. Computer science	1	2	9
9. Other(s)________________________________ ____	1	2	9

d. Are the following computer-based learning activities occuring in the district? (1=Yes; 2=No; 9=No information)

1. Drill & practice	1	2	9
2. Tutorial	1	2	9
3. Simulations	1	2	9
4. Microworlds	1	2	9
5. Games	1	2	9
6. Tests	1	2	9
7. Computer literacy	1	2	9
8. Programming	1	2	9
9. Other(s)________________________________ ____	1	2	9

e. In the respondent's judgment, how well integrated are microcomputer activities with regular, ongoing instruction?
(1=Not integrated; 4=Highly integrated; 9=Don't Know or otherwise inapplicable) 1 2 3 4 9

10. Changes

a. Were new personnel hired specifically for their expertise with computers or computer-based instruction?
(1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, describe:

b. Have there been official changes in job titles or pay levels for computer-using teachers? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, describe:

c. To what extent have microcomputers affected the way teachers teach, in the respondent's judgment?
(1=Not at all; 4=A great deal; 9=No information) 1 2 3 4 9

Any comments:

To what extent have microcomputers affected the way students learn, in the respondent's judgment?
(1=Not at all; 4=A great deal; 9=No information) 1 2 3 4 9

Any comments:

11. Recommendations regarding instructional uses of microcomputers

a. Training Programs

Should the following content areas be covered in inservice training programs? (1=Yes; 2=No; 9=Not mentioned by respondent)

1. Programming	1	2	9
2. Operation of the microcomputer	1	2	9
3. Selection/evaluation of courseware	1	2	9
4. Instructional uses of microcomputers	1	2	9
5. Administrative uses of microcomputers	1	2	9
6. Coordination of microcomputers with instruction	1	2	9
7. Computer Literacy	1	2	9
8. Other(s)____________________	1	2	9

What other features should be included in the ideal inservice training? List below for each category:

1. Location:

2. Length:

3. Organizational incentive(s):

4. Other:

b. List any recommendations made for how courseware could be improved to be more useful to teachers and students:

c. List any advice for getting districts and teachers more involved with computers.

PRINCIPAL INTERVIEW GUIDE

Instructions to Interviewer: Briefly explain that the purpose of this interview is to gather information about the organizational environment for instructional use of microcomputers in the school such as how microcomputers were implemented, what steps were taken to get things going, what they're doing to support microcomputers for instruction, and the kinds of changes that have occurred.

Although we will focus on certain questions, we are interested in any other information the respondent feels will help us understand the organizational structure in the school that has been established for using microcomputers, and the process for implementing computers, including future plans.

Assure the respondent that his or her responses will remain anonymous. No one else in the district or school will have access to them, nor will anyone else who is not directly associated with the research study. In addition, schools and district will have pseudonyms in any written reports.

If, after the interview, the respondent thinks of other information which will help us, he or she may call or write to us at Rand.

After the interview, collect any relevant documents available, such as policy about computers, curriculum specification, agenda and materials used for staff development.

Principal Interview Guide

District Name: ____________________________ School ______________________

Respondent's Title: ______________________

First, I'd like to talk about how and why the microcomputer came to be used for instruction in this school.

1. How did microcomputers come to be used for instruction in this school?

   Probe--whether primary impetus came from district or school administration, bottom up (grass-roots), or combination of grass-roots and administrative.

2. Who supported the introduction of microcomputers in this school? What reasons did they give for supporting computers? (names are not necessary; just tell me their role, e.g., teachers, parents, school board.)

   Has there been any resistance to the introduction of microcomputers in the school? What kinds of concerns have been expressed? (e.g., lack of funds, lack of interest).

The next question focuses on the ways microcomputers were implemented in this school--how specific decisions were made--on equipment, training teachers or other personnel, and so on.

3. As microcomputers were implemented in this school, who had primary responsibility for decisionmaking in the following areas: (No names necessary, just the position of persons involved.)

Equipment

Software

Staff development/teacher training

Physical Arrangement

Let me ask you now about current school policies toward computers.

4a. Does the school have a formal, written policy toward computers?

_____ YES: (Obtain copy of statement if possible.)

_____ NO

4b. At present, what are the school's major goal Hs for using microcomputers in instruction? Is there a general strategy for introducing computers into the school?

4c. How much progress have you made in reaching these goals?

Next, I'd like to ask about support and training provided for teachers that use computers in this school.

5a. Are technical assistance or material resources routinely provided to the school by the district? (e.g., programmer, curriculum specialist.) IF YES, describe:

5b. Does the school provide any technical assistance or resources for computer-using teachers. IF YES, describe:

5c. Does the school provide any special incentives to teachers interested in using computers, such as credit or release time, for example?

5d. Ideally, what kinds of support services would you like to have available from the district? What would you like to be able to provide in the school?

6. Is any staff development or training about microcomputers provided within the school, aside from any provided by the ditrict?

Yes, has provided ☐

Yes, but not yet provided ☐

No, none provided or planned ☐

(a) *IF YES, what kinds of staff development were/are provided?*

(Probe for specific information about organization of training and what topics were covered).

(b) IF YES, how many hours of training does each teacher get, on average? __________ hours

7. Please evaluate the training provided by the district and school (whichever are relevant).

How satisfied are you with the training provided? What features were you especially satisfied or dissatisfied with?

Now I have a few questions about school funding for microcomputer use in instruction.

8. (a) What, if any, school budget categories (other than discretionary funds) provide funds for computer-related services, equipment, software, and the like?

Describe:

(b) Do you use any of your discretionary funds for computer-related purposes?

If so, what?

(c) Does the school have or rely on other outside sources of funds for computer-related purposes (PTA, parent fund raising, state grants, etc.)?

Yes ____ No ___

(d) Do the sources of funding limit or constrain the use of the computers in any special way (e.g., only gifted or disadvantaged students could use the computers).

9. Now I'd like to ask about some of the ways in which microcomputers are used for instruction in this school.

   (a) How many microcomputers are there in the school?

   (b) Where are the computers located (i.e., how many are in labs and classes)? Have you used physical location to encourage computer use by teachers?

   Probe--location and arrangement of computers, including number in classes and labs

   (c) What subject matter areas are microcomputers being used in?

(d) What kinds of educational programs are being run on the microcomputer? (Probe modes of use; i.e., drill and practice or tutorials for basic skills with disadvantaged kids, etc.)

(e) How well integrated are microcomputer activities with regular, ongoing instruction?

10. What kinds of changes have taken place since microcomputers came to this school?

(a) Have any teachers been hired specifically for their expertise with computers or with computer-based education?

(b) How much, if at all, have microcomputers affected the way teachers teach? The way students learn?

(c) Have you had much experience yourself with computers? What are your general attitudes about the so-called computer revolution and its impact on education?

11. Finally, I'd like to ask for some of your recommendations regarding instructional uses of microcomputers

    (a) What recommendations would you make about the organization and content of teacher training for microcomputers in instruction?

    Probe--features of the optimal service program (location, length, organizational incentives) and training topics

(b) Based on your experiences with microcomputers in instruction, what recommendations can you make on how courseware could be improved to be more useful to teachers and students?

(c) In general, is there any advice you would give for getting teachers and schools more involved with microcomputers?

Revised 2/11/83

SITE SURVEY INSTRUMENT: PRINCIPAL INTERVIEW

School District Name___________________________School _______________________

Coder________________

Respondent's Title (Circle one):

a. Principal	1
b. Assistant Principal	2
c. Other:__________________________________	9

Knowledgeability of the respondent on administrative matters (1=Not knowledgeable; 4=Extremely knowledgeable)	1	2	3	4
Knowledgeability of the respondent on instructional uses of computers (1=Not knowledgeable; 4=Extremely knowledgeable)	1	2	3	4

1. How microcomputers came to be used for instruction in the school (Circle one):

a. Administrative decision in district	1
b. Administrative decision in school	2
c. Combination of administrative and grass-roots	3
d. Grass roots or bottom-up from teachers	4
e. Other____	9

Describe:

2. Support and Resistance to the Introduction of Microcomputers

To what degree did each of the following support or resist the implementation of microcomputers? (1=Resisted strongly; 2=resisted somewhat; 3=neutral or mixed; 4=supported somewhat; 5=supported strongly; 9=No information)

a. District administrator	1	2	3	4	5	9
b. Principal	1	2	3	4	5	9
c. Teacher(s)	1	2	3	4	5	9
d. Parents	1	2	3	4	5	9
e. Other(s)______________________________	1	2	3	4	5	9

What reasons were given for supporting computer use?

What kinds of concerns were expressed?

3. Decisions on equipment, software, staff development, and physical arrangement in the school.

For each of the following areas, who had primary responsibility for decision-making: (1=District administration; 2=School administration; 3=Individual teachers; 8=Other (describe); 9=No information)

a. Computer equipment IF OTHER, identify:	1	2	3	8	9

b. Educational software 1 2 3 8 9
IF OTHER, identify:

c. Staff development/teacher training 1 2 3 8 9
IF OTHER, identify:

d. Physical arrangement of computers 1 2 3 8 9
IF OTHER, describe:

4. School Policies, Goals, and Strategies

a. Does the school have a formal, written policy toward computers? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, Note whether a written policy was obtained: Yes No

b. How important for the school are the following goals for using microcomputers in instruction? (1=Not important; 2=minor importance; 3=major importance; 9=No information regarding goal)

1. Mastery of basic skills (i.e, arithmetic; reading) 1 2 3 9
2. Acquisition of higher cognitive skills (i.e., mastery of concepts or problem-solving procedures) 1 2 3 9
3. Motivation (e.g., positive subject-matter attitudes) 1 2 3 9
4. Classroom management (i.e., orderly work environment; student cooperation or teamwork) 1 2 3 9
5. Computer literacy or enrichment 1 2 3 9
6. Administrative efficiency (including CMI) 1 2 3 9
7. Serve special students 1 2 3 9
8. Other(s)______________________________________ 1 2 3 9
____

IF SERVING SPECIAL STUDENTS IS A GOAL; note which (e.g., gifted, handicapped, title I/low achievers, etc.):

c. How much progress has the school made in reaching these goals, according to the respondent?
(1=No Progress; 4=Great Progress; 9=Not applicable) 1 2 3 4 9

5. Technical Assistance and Material Resources

a. According to the respondent, are technical assistance or material resources in support of microcomputer use routinely provided by the district? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, what technical assistance or material resources are provided?

b. According to the respondent, are technical assistance or material resources in support of microcomputer use routinely provided by the school? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, what technical assistance or material resources are provided?

c. Does the school provide any special incentives to teachers interested in computers? (1=Yes; 2=No; 9=Not applicable)	1 2 9

IF YES, describe:

d. What kinds of support services would the respondent like to have from the district?

What kinds of support would the respondent like to provide in the school?

6. Staff development/teacher training

Is the school providing staff development or training about microcomputers? (Circle one)

1. Not provided or planned	1
2. Not yet provided but planned	2
3. Yes, has or is providing	3

a. IF PROVIDED OR PLANNED, Describe the organization of staff development:

IF PROVIDED OR PLANNED, List the topics covered/to be covered:

c. Number of hours of training, on average, per teacher:
(Code 999 if no training or don't know) ________

7. Satisfaction with staff development/training

How satisfied is the respondent with district staff development/training? (1=not satisfied; 4=extremely satisfied; 9=No training provided or not applicable) 1 2 3 4 9

List features that were especially satisfactory:

List features that were not especially satisfactory:

How satisfied is the respondent with school staff development/training? (1=not satisfied; 4=extremely satisfied; 9=No training provided or not applicable) 1 2 3 4 9

List features that were especially satisfactory:

List features that were not especially satisfactory:

8. School funding for microcomputer use in instruction

   a. What budget categories, other than discretionary funds, provide funds related to computers?

   b. Are school discretionary funds used for computer-related purposes? (1=Yes; 2=No; 9=Not applicable) 1 2 9

   c. Do outside sources of funding (e.g., national or state grants, private donors) provide funds that can be used for computer related purposes? (1=Yes; 2=No; 9=No information) that apply) 1 2 9

   IF YES, Describe funding sources:

   d. Do sources of funding limit or constrain computer use? (1=Yes; 2=No; 9=Not applicable) 1 2 9

   IF YES, Describe:

9. Use of Microcomputers for Instruction in the School

a. How many microcomputers in the school ? (999=Don't Know) ____________

b. How many microcomputers are located in teachers' classrooms? (999=Don't Know) ____________

Has the respondent used physical location to encourage computer use by teachers? (1=Yes; 2=No; 9=Not applicable) 1 2 9

Describe location and arrangement of microcomputers in the school:

c. Are computers used in the following subject-matter areas? (1=Used; 2=Not used; 9=Not applicable or no information)

1. Elementary mathematics	1	2	9
2. Secondary mathematics	1	2	9
3. Elementary science	1	2	9
4. Secondary science	1	2	9
a. Biology	1	2	9
b. Chemistry	1	2	9
c. Physics	1	2	9
d. Other(s)____________________	1	2	9
5. English (language arts)	1	2	9
6. Foreign Languages	1	2	9
7. Social studies	1	2	9
8. Computer science	1	2	9
9. Other(s)____________________ ____________________	1	2	9

d. Are the following computer-based learning activities occurring in the school? (1=Yes; 2=No; 9=No information)

1. Drill & practice	1	2	9
2. Tutorial	1	2	9
3. Simulations	1	2	9
4. Microworlds	1	2	9
5. Games	1	2	9
6. Tests	1	2	9
7. Computer literacy	1	2	9
8. Programming	1	2	9
9. Other(s)______________________________ ______________________________	1	2	9

e. In the respondent's judgment, how well integrated are microcomputer activities with regular, ongoing instruction? (1=Not integrated; 4=Highly integrated; 9=Don't Know or otherwise inapplicable) 1 2 3 4 9

10. Changes

a. Were new teachers hired specifically for their expertise with computers or computer-based instruction? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, describe:

b. To what extent have microcomputers affected the way teachers teach, in the respondent's judgment? (1=Not at all; 4=A great deal; 9=No information) 1 2 3 4 9

Any comments:

To what extent have microcomputers affected the way students learn, in the respondent's judgment?
(1=Not at all; 4=A great deal; 9=No information) 1 2 3 4 9

Any comments:

c. How much experience has the respondent had with computers? (1=None; 2=A little; 3=Some; 4=A great deal) 1 2 3 4 9
IF ANY, describe:

How would you characterize the respondent's attitudes toward computers in education?
(1=Negative; 2=Slightly negative; 3=Mixed or neutral; 4=Slightly positive; 5=Positive) 1 2 3 4 5 9

11. Recommendations regarding instructional uses of microcomputers

a. Training Programs

Should the following content areas be covered in inservice training programs? (1=Yes; 2=No; 9=Not mentioned by respondent)

1. Programming	1	2	9
2. Operation of the microcomputer	1	2	9
3. Selection/evaluation of courseware	1	2	9
4. Instructional uses of microcomputers	1	2	9
5. Administrative uses of microcomputers	1	2	9
6. Coordination of microcomputers with instruction	1	2	9
7. Computer Literacy	1	2	9
8. Other(s)______________________________	1	2	9

____

What other features should be included in the ideal inservice training? List below for each category:

1. Location:

2. Length:

3. Organizational incentive(s):

4. Other:

b. List any recommendations made for how courseware could be improved to be more useful to teachers and students:

c. List any advice for getting teachers and schools more involved with computers.

COMPUTER QUESTIONNAIRE FOR TEACHERS

DIRECTIONS

- Please try to answer every question that applies to you.
- Answer most questions by checking items in a list. The directions will indicate when a different type of response is required.
- If you want to comment on any question, please do so in the left margin. Your comments will be read and taken into account.
- When you have completed the questionnaire, please keep it until you meet one of the study team members or return in the attached, self-addressed stamped envelope to Abby Robyn, The Rand Corporation, 1700 Main Street, Santa Monica, 90406.

STATEMENT OF CONFIDENTIALITY

"All information which would permit identification of respondents or their schools will be regarded as strictly confidential, will be used only for the purposes of the study and will not be disclosed or released for any other purpose without prior consent, except as required by law."

ID # 01-06/

CARD 01 07-08/

SECTION 1: COMPUTERS IN THE CLASSROOM

1. In your opinion, how well designed (i.e., pedagogically sound) are most programs or courseware that are available for use with classroom computers?

Very well designed............1 ☐ 09/
Somewhat well designed.........2 ☐
Somewhat poorly designed.......3 ☐
Very poorly designed...........4 ☐

2. How much special training do you think teachers need in order to start using microcomputers in their classrooms?

A great deal...................1 ☐ 10/
Moderate amount................2 ☐
Little or none.................3 ☐
Don't know.....................4 ☐

3. Based on your own observations, how successful have the teachers in your district been in using computers in instruction?

Very successful................1 ☐ 11/
Somewhat successful............2 ☐
Not very successful............3 ☐
Not successful at all..........4 ☐
Don't know.....................5 ☐

SECTION 2: YOUR OWN COMPUTER USE

1. Have you ever used any kind of computer for teaching, personal use, or any reason? Count any "hands on" use, including computer games.

YES 1 ☐ → (Answer Q.2-11, this section) *12/*

NO 2 ☐ → (Skip to Section 3, page 7)

2. Do you use computers for the following purposes? IF YES, how long have you used them and for about how many hours per week (on average, over the past academic year)?

Do you use computers for:

	How long have you used them for this purpose?	How many hours per week?	
A. Classroom instruction?			
1 ☐ YES →	_____YRS _____MONTHS	_____HOURS/WEEK	*13-19/*
2 ☐ NO			
B. Other teaching functions?			
1 ☐ YES →	_____YRS _____MONTHS	_____HOURS/WEEK	*20-26/*
2 ☐ NO			
C. Outside teaching?			
1 ☐ YES →	_____YRS _____MONTHS	_____HOURS/WEEK	*27-33/*
2 ☐ NO			

CARD 01

3. CLASSROOM USE - Please answer questions 3A-3D if you use computers in the classroom. If you do not use them for this purpose, please SKIP TO Q.4 below.

3A. Approximately how many different disks or tapes have you used in your classes in the last year?

OF DISKS OR TAPES ________ *34-35/*

3B. Are you generally able to test software before you begin to use it in your classes?

YES 1 ☐ *36/*

NO 2 ☐

3C. Have you ever adapted or changed educational software that you obtained in order to make it more suitable for your classes?

YES 1 ☐ *37/*

NO 2 ☐

3D. Have other teachers in your school or district ever used you as a resource person for computer applications in classrooms?

YES 1 ☐ *38/*

NO 2 ☐

4. Have you ever used a:

A. Minicomputer? YES 1 ☐ *39/*

NO 2 ☐

B. Mainframe computer? YES 1 ☐ *40/*

NO 2 ☐

5. Have you ever used a microcomputer?

YES 1 ☐ ⟶ (Answer Q.5A-5C.) 41/

NO 2 ☐ ⟶ (Skip to Q.6 on next page.)

5A. How many different types or makes of microcomputers (e.g., Apple, Atari, TRS-80) have you used?

# OF TYPES USED ________ 42-43/

5B. For what purposes have you used microcomputers, either for teaching or outside of teaching? (Please check all purposes that apply)

PURPOSES	HAVE USED IN MY TEACHING	HAVE USED OUTSIDE MY TEACHING	
	1	1	
A. Text editing	☐	☐	44-45/
B. Computation	☐	☐	46-47/
C. Simulations	☐	☐	48-49/
D. Games	☐	☐	50-51/
E. Information storage/record keeping (e.g., CMI)	☐	☐	52-53/
F. Drill and practice	☐	☐	54-55/
G. Tutorial sessions	☐	☐	56-57/
H. Testing	☐	☐	58-59/
I. Computer-assisted design of materials	☐	☐	60-61/
J. Computer literacy	☐	☐	62-63/

5C. Which of the following microcomputer-related equipment have you used, either for teaching purposes or outside of teaching? (Please check all that you have used.)

EQUIPMENT	HAVE USED IN MY TEACHING	HAVE USED OUTSIDE MY TEACHING	
	1	1	
A. Floppy disk drives	☐	☐	64-65/
B. Cassette player (to load and store programs)	☐	☐	66-67/
C. Modem/acoustic coupler	☐	☐	68-69/
D. Computer controlled printer	☐	☐	70-71/
E. Hard disk drives	☐	☐	72-73/

CARD 01

6. Which kind of computer did you use first?

Mainframe 1 ☐ 09/

Minicomputer 2 ☐

Microcomputer 3 ☐

7. Have you ever written any original computer programs or software for any purpose?

YES 1 ☐ → (Answer Q.7A-7B.) 10/

NO 2 ☐ → (Skip to Q.8, below.)

7A. Approximately how many programs have you written?

(1) For instructional purposes? ________ 11-12/

(2) For any other purposes? ________ 13-14/

7B. In which languages have you written programs? (Check all that apply) 15-20/

1

Basic ☐

Cobol ☐

Fortran ☐

1

Pilot ☐

Pascal ☐

Other ☐

What language(s) ________

____

8. Have you ever taught about computers to other teachers or district staff?

YES 1 ☐ 21/

NO 2 ☐

9. Have you ever held a job other than teaching in which you worked extensively with computers?

YES 1 ☐ → What kind of job? ____________ 22/

NO 2 ☐ ________________

10. Have you been active in any computer clubs or user groups during the past year?

YES 1 ☐ 23/

NO 2 ☐

11. What (if any) computer magazines do you read regularly?

24-30/

1

Computing Teacher ☐

Byte ☐

Creative Computing ☐

Educational Technology ☐

1

Classroom Computer News ☐

AEDS Journal ☐

Other - Which? ☐

____

CARD 02

SECTION 3: YOUR BACKGROUND

1. About what percentage of your undergraduate coursework was devoted to the following subject areas: (TOTAL TO 100%)

A. Biological sciences ______% *31-32/*

B. Physical sciences (e.g., chemistry, physics) ______% *33-34/*

C. Social sciences ______% *35-36/*

D. Computer science ______% *37-38/*

E. Humanities ______% *39-40/*

F. Mathematics ______% *41-42/*

G. Education ______% *43-44/*

H. General science ______% *45-46/*

I. Other ______% *47-48/*

100 %

2. Please list your undergraduate degree(s).

ACADEMIC MAJOR	YEAR GRANTED	
(A)________________________________	__________	*49-53/*
(B)________________________________	__________	*54-58/*

or CHECK BOX IF NO DEGREE ☐ *59/*

3. Have you taken any courses beyond the bachelor's degree?

YES 1 ☐ ⟶ (Answer Q.3A-3B.) *60/*

NO 2 ☐ ⟶ (Skip to Q.4.)

3A. About what percentage of your coursework beyond the bachelor's degree was devoted to the following subject areas (include any courses, whether or not you were formally pursuing a graduate degree): (TOTAL TO 100%)

A. Biological sciences ______% *61-62/*

B. Physical sciences (e.g., chemistry, physics) ______% *63-64/*

C. Social sciences ______% *65-66/*

D. Computer science ______% *67-68/*

E. Humanities ______% *69-70/*

F. Mathematics ______% *71-72/*

G. Education ______% *73-74/*

H. General science ______% *75-76/*

I. Other ______% *77-78/*

100 %

CARD.03

3B. Please list your graduate degree(s)?

	DISCIPLINE	DEGREE	YEAR GRANTED	
A.	______________________	__________	__________	*9-14/*
B.	______________________	__________	__________	*15-20/*
C.	______________________	__________	__________	*21-26/*

or CHECK BOX IF NO DEGREE ☐ *27/*

4. What regular or lifetime teaching certificates do you have?

A. ____ *28-29/*

B. ____ *30-31/*

C. ____ *32-33/*

D. ____ *34-35/*

5. How many years of full-time teaching experience have you completed, including the current year?

YEARS OF TEACHING ________ *36-37/*

6. Please list the names of the different courses you are teaching this academic year. For each one, please fill in the grade level, and indicate how many years you have taught the courses, including this year.

	COURSE NAME	GRADE LEVEL	NUMBER OF YEARS TAUGHT	
A.	____________________	________	________	38-43/
B.	____________________	________	________	44-49/
C.	____________________	________	________	50-55/
D.	____________________	________	________	56-61/
E.	____________________	________	________	62-67/
F.	____________________	________	________	68-73/

CARD 04

7. What degree of confidence do you have in teaching the following subjects at this school? Please answer for each subject, whether or not you currently teach it.

	SUBJECT	NOT AT ALL CONFIDENT	SOMEWHAT CONFIDENT	MODERATELY CONFIDENT	VERY CONFIDENT	
		1	2	3	4	
A.	Mathematics	☐	☐	☐	☐	09/
B.	General science	☐	☐	☐	☐	10/
C.	Biological sciences	☐	☐	☐	☐	11/
D.	Physical sciences	☐	☐	☐	☐	12/
E.	Computer science	☐	☐	☐	☐	13/
F.	Social sciences	☐	☐	☐	☐	14/
G.	Humanities	☐	☐	☐	☐	15/
H.	Other (please specify)	☐	☐	☐	☐	16/

____

8. Can you touch type? (Check one)

YES 1 ☐ 17/

NO 2 ☐

SECTION 4: OPINIONS ABOUT COMPUTERS

1. In this section, please indicate how strongly you agree or disagree with these statements about computers. If you strongly agree with a statement circle a 1, if you agree somewhat then circle the 2, etc.

   Please be honest and candid in your responses, and try to answer each of the statements.

	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE	
A. Students will lose their ability to reason if they let the computers do their work for them.	1	2	3	4	*18/*
B. I have a positive attitude toward computers.	1	2	3	4	*19/*
C. Computers make complex things easier for students to understand.	1	2	3	4	*20/*
D. Teachers in this district are not provided with the tangible support needed to use computers in instruction.	1	2	3	4	*21/*
E. Students should not be allowed to play games on classroom computers.	1	2	3	4	*22/*
F. This district would like teachers to get involved with computers.	1	2	3	4	*23/*
G. Teachers need programming skills in order to use computers successfully in their teaching.	1	2	3	4	*24/*
H. I would like to own (or do own) a computer.	1	2	3	4	*25/*
I. Students don't need gadgets like computers to teach them "the basics."	1	2	3	4	*26/*
J. To make it in modern society, nearly everyone will need computer skills.	1	2	3	4	*27/*

THANK YOU VERY MUCH FOR YOUR PARTICIPATION

CARD 04

REVISED 2/9/83

INTERVIEW GUIDE: TEACHERS USING MICROCOMPUTERS

I. Support and Context
  A. District/School Policies
  B. Student Characteristics

II. Computer Use
  A. Instructional Activities
  B. Goals for students
  C. Variety of computer-based learning activities
  D. Integration of computer use with instruction
  E. Feedback
  F. Evaluations of Computer use

III. Computer Knowledge

School ______________________ Teacher ______________________

Grade Level(s)______________ Subject ______________________

(Check one) Lab_______ or Classroom Teacher ____________

```
******************************************
*                                        *
*  PICK UP QUESTIONNAIRES FROM TEACHERS  *
*                                        *
*   __picked up                          *
*                                        *
*   __mailed in                          *
*                                        *
*   __not picked up or mailed in yet     *
******************************************
```

TEACHER KNOWLEDGE AND COMPUTER USE: TEACHER INTERVIEW GUIDE

INSTRUCTIONS: Briefly explain that the purpose of the interview is to find out how microcomputers are used for instruction by teachers and students, and that during the course of the interview we will touch on a number of topics related to the school/district climate for microcomputer use in instruction and their goals and experiences with microcomputers in instruction.

I. Support and Context

First, I'd like to ask you about how you came to use microcomputers for instruction in this school or district.

1. How did you get started using microcomputers in instruction?
   Probe--where impetus came from (e.g., top down; on own)?

2. Is continuing support for using microcomputers in teaching--either financial or technical (e.g., programmer, curriculum specialist)--provided by the district/school?

   (a) (IF YES) Describe and evaluate.

   (b) (ALL) Ideally, what kinds of support services would you like to have available in the school or district?

3. Is the district or school providing any staff development or training on how to use microcomputers in instruction? (IF NO, SKIP TO QUESTION 4)

   (a) If yes, how was it organized? (Probes--types; location; length of training)

   (b) What topics were covered in the training program(s)?

   (c) Did you participate in this training?

      1. If yes:

         (a) What topics were most helpful to you?

         (b) What topics were least helpful?

4. What kind of INSERVICE programs do you think would be valuable for training teachers in how to use microcomputers?

   Probes--features of the optimal inservice program, including:

   Content (topics that should and should not be covered):

   Location:

   Length:

   Organizational incentive:

   Other (specify):

5. What about PRESERVICE training? Would you recommend any differences from the inservice training programs you just describe (probes--content of training, types of experiences)?

The next questions concern your plans for instruction for the class we (will) observe(d), with respect to [subject matter].

6. Just for background information, could you tell me something about the characteristics of the students in the classes (or lab) in which computers are used?

   Average number per class period ____

   Percent minority ____

   Percent male ____

   SES (circle one) LO MED HI

   Ability Level LO MIXED HI

II. Computer Use

7. Subject Matter: INTERVIEWER: Note title of class __________________.

   (a) What major content topics do you cover in this class?

   (b) For which of these topics do you plan to use the microcomputer for instruction?

(c) Do you coordinate the course textbook or other teaching and curricular aids (e.g., worksheets, labs) with the computer?

IF YES, describe which ones:

(d) Overall, how well have you been able to integrate computer use with the rest of your instruction in (subject matter)?

Probe: For teacher's evaluation of integration of subject-matter and computer use

8. Goals and Objectives

(a) What are your major goals and objectives for your class in [subject matter]?

Probe--for cognitive (able to do, know) and affective (feelings and attitudes about subject matter) goals; preferred learning environments.

(b) To what degree is the microcomputer supposed to help accomplish the subject-matter goals you've just mentioned?

Probe--Teachers' plans for using microcomputers to help them with subject-matter goals, as opposed to any unique goals for microcomputer use (e.g., enrichment)

(c) How successful has microcomputer use actually turned out to be with respect to the goals and objectives you've set for it?

I'd like to ask you in more detail about the ways in which you use microcomputers in your [subject matter] in instruction with this class.

9. Allocation of Time

(a) How much time do you typically use the microcomputer as an instructional aid for your teaching; e.g., in demonstrations/labs? (minutes/week)

(b) How much time does a typical student spend working with the microcomputer (minutes/week)?

10. Computer Activities

(a) What kinds of computer-based learning activities are your students engaged in with microcomputers (e.g., drill and practice; tutorial; simulation; games; microworlds; data analysis, problem solving, literacy, programming)?

Probe: How extensively each mode is used

(b) How do you make transitions from non-computer activities to computer activities and back?

11. Teaching Strategies and Grouping Principles

(a) What is your strategy for assigning students to different kinds of computer uses?

Probe--Do you have a rule of thumb for assigning the type or content of CAI to students based on ability, intellect, other?

(b) Do students use computers primarily individually or in groups? How are these groups formed? How do you allocate computer time among students or groups of students?

Probe--how are groups formed; whether and why different subsets of students spend differing amounts of time on the computer

(c) Do you have any rules for students who use the microcomputer?

12. Teacher's Evaluation of Courseware

(a) Do you select the courseware you use for instruction?

Probe--How is it obtained? If teacher doesn't select it, who does?

(b) IF TEACHER SELECTS COURSEWARE, ask: What features do you look for in selecting courseware? What features do you try to avoid?

Probe--courseware attributes aside from content.

(c) Do you, your school, or district have standard criteria for evaluating instructional courseware? If so, what are they (or attach copy)?

(d) How could courseware be improved, based on your experience?

13. Other than Instructional Uses of Microcomputers

(a) Moving away from instruction, do you use the microcomputer to keep records on students? Do you use it for testing?

14. I'd like to ask you some questions now about your overall evaluations of the effects microcomputers have had on instruction thus far.

(a) Have you made any changes in the ways you use microcomputers in instruction since you first began? (IF YES) What has changed?

Probe--altering modes of use; rejecting or selecting courseware; revisions of goals or plans for use.

(b) How do you determine whether microcomputer activities are working out?

Probe--Whether and how teacher monitors "success of microcomputer use; how often teacher monitors

III. Computer Knowledge

NOTE TO INTERVIEWER: ASK THE FOLLOWING QUESTIONS ONLY IF TIME PERMITS

Now I'd like to ask you some questions about the microcomputers that you use, both in conjunction with your job and outside of your teaching.

15. If another teacher wanted to start using microcomputers in instruction what would you tell him or her about the [microcomputer you use] for example, its capabilities and limitations? What equipment and arrangements would you recommend?

    Probe: Knowledge of major parts and configurations

16. What about courseware for the [microcomputer you use]? What varieties of courseware would you recommend? What would you not recommend? What are the particular advantages and disadvantages for the student?

    Probe: Knowledge of modes of use; courseware features

Revised 2/9/83

SITE SURVEY INSTRUMENT: TEACHER INTERVIEW

School District Name________________________School___________________________

Teacher Interviewed_________________________Grade Level(s)__________________

Subject Matter______________________________Coder___________________________

Respondent (Circle One): Classroom Teacher Lab Supervisor

SUPPORT AND CONTEXT

1. Primary reason teacher got started using microcomputers in instruction (Circle one):

1. Impetus from district administration or school board	1
2. Impetus from school administration (e.g., principals)	2
3. Own initiative	3
6. Don't know	9

2. Continuing support for using microcomputers in teaching

   a. What support for microcomputer use is routinely provided? (Circle one)

1. None	1
2. Technical or financial support only	2
3. Both technical and financial support	3
4. Don't Know	9

IF SUPPORT IS PROVIDED:
How adequate is the level of support provided?
(1=not at all; 4=extremely adequate; 9=not applicable) 1 2 3 4 9

IF SUPPORT IS PROVIDED, Describe nature of support:

b. What kinds of support services would the respondent like to see?

3. Staff development

According to the respondent, is staff development or training provided by the district?
(1=Yes; 2=No; 9=Don't Know) 1 2 9

a. IF PROVIDED, Describe the organization of staff development:

b. IF PROVIDED, List the topics covered in staff development:

c. Did the teacher participate in staff development?
(1=Yes; 2=No; 9=Staff development not provided) 1 2 9

IF TEACHER PARTICIPATED:
1. List the topics found most helpful:

2. List the topics found least helpful:

4. Ideal inservice training programs

a. Should the following content areas be covered in inservice training programs? (1=Yes; 2=No; 9=Not mentioned by respondent)

1. Programming	1	2	9
2. Operation of the microcomputer	1	2	9
3. Selection/evaluation of courseware	1	2	9
4. Instructional uses of microcomputers	1	2	9
5. Administrative uses of microcomputers	1	2	9
6. Integration of microcomputers with instruction	1	2	9
7. Computer Literacy	1	2	9
8. Other(s)______________________________	1	2	9
____________________________________			

b. What other features should be included in the ideal inservice training? List below for each category:

1. Location:

2. Length:

3. Organizational incentive(s):

4. Other:

5. Should the content of preservice training programs differ from that of inservice training programs?
(1=Yes; 2=No; 9=Don't Know) 1 2 9

IF YES, Describe:

6. Student Characteristics

Average number of students per class period: ____________
Approximate percentage minority status: ____________
Approximate percentage male: ____________
Socioeconomic level of class: (Circle one) Lo Medium Hi
Ability level of students: (Circle one) Lo Mixed Hi

CLASSROOM COMPUTER USE

7. Instructional Activities

Title of class observed/discussed: ______________________________

a. What are the major content topics that the respondent covers in this class?

b. How extensively is the microcomputer used with the major topics in this class?
(1=Not at all; 4=Extremely; 9=Not Applicable) 1 2 3 4 9

What major topics is the computer used with?

c. To what extent is the computer coordinated with other instructional activities? (e.g., texts, labs, dittos)
(1=Not at all; 4=Extremely; 9=Not Applicable) 1 2 3 4 9

Which instructional activities is the computer most frequently used with? List below:

d. In the respondent's judgment, how well integrated are microcomputer activites and "regular" instruction?
(1=Not at all; 4=Extremely; 9=Not Applicable) 1 2 3 4 9

8. Goals and Objectives

a. How much does the respondent stress or emphasize these goals and objectives for his/her students in the subject matter?
(1=Not at all; 4=Extremely; 9=Not applicable)

1. Mastery of basic skills (i.e., reading; arithmetic) 1 2 3 4 9
2. Acquisition of higher cognitive skills (e.g., mastery of concepts; problem-solving procedures) 1 2 3 4 9
3. Motivation (e.g., positive subject-matter attitudes) 1 2 3 4 9
4. Classroom management (i.e., orderly work environment; student cooperation or teamwork) 1 2 3 4 9
5. Other(s)____ 1 2 3 4 9

b. To what extent is the microcomputer supposed to help accomplish the following subject matter goals? (1=Not help at all; 4=Help a great deal; 9=Not named as a subject matter goal)

1. Mastery of basic skills (i.e., reading; arithmetic) 1 2 3 4 9
2. Acquisition of higher cognitive skills (e.g., mastery of concepts; problem-solving procedures) 1 2 3 4 9
3. Motivation (e.g., positive subject-matter attitudes) 1 2 3 4 9
4. Classroom management (i.e., orderly work environment; student cooperation or teamwork) 1 2 3 4 9
5. Other(s)____ 1 2 3 4 9

Does the respondent mention any goals for microcomputer use in its own right? (e.g., literacy or enrichment) (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, list unique goals for classroom microcomputer use:

c. How successful has microcomputer use actually turned out to be with respect to the goals and objectives established for its use? (1=Not successful; 4=Highly Successful; 9=Not applicable) 1 2 3 4 9

Any Comments:

9. Allocation of Time

a. How many minutes per week does the respondent use a microcomputer as a teaching aid (i.e., for demonstration or illustration)?

_________minutes per week

b. How many minutes per week do students typically spend working with a microcomputer?

_________minutes per week

10. Computer-based learning activities

a. To what extent are the following types of computer-based learned activities used in the class under discussion? (1=Not used; 2=Used occasionally; 3=Used extensively; 9=No information)

1. Drill and Practice	1	2	3	9
2. Tutorial	1	2	3	9
3. Simulation	1	2	3	9
4. Microworlds	1	2	3	9
5. Games	1	2	3	9
6. Other____	1	2	3	9

b. Are transitions made between computer and non-computer activities?
(1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, Describe how transitions are made:

11. Teaching Strategies and Grouping Principles

a. Are students matched to modes or types of computer-based learning activities (i.e., drill and practice; tutorial; etc) based on ability?
(1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, Describe how activities relate to student ability.

Are students matched to content of CAI (i.e., lesson difficulty or subject matter) based on ability?
(1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, Describe how content relates to student ability.

Is some other strategy used for assigning type or content of CAI to different students (e.g., grade-level; sex; etc)
(1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, Describe how this is done:

b. How are students grouped for computer activities, primarily? (1=individually; 2=in pairs; 3=in groups of three or more; 9=Not applicable) 1 2 3 9

IF STUDENTS ARE GROUPED; on what basis are groups formed? (1=subject matter ability; 2=computer ability; 3=other basis; 9=groups not used or not applicable) 1 2 3 9

IF OTHER, specify basis of grouping:

Are all users allotted equal time with the computer? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF NOT, Describe how time is allocated.

c. What rules has the respondent established for the following activities related to classroom computer use? (1=Restricted; 2=Not restricted; 9=Rule not mentioned)

1. Games 1 2 9
2. Interaction around computer (e.g., talking) 1 2 9
3. Operation of computer (e.g., loading disks) 1 2 9
4. Access to computer (e.g., when it can be used) 1 2 9
5. Computer time (e.g., duration of use) 1 2 9
6. Other ______________________________ 1 2 9

____

12. Courseware

a. Does the respondent select the courseware s/he uses in instruction? (1=Yes; 2=No; 9=Not applicable) 1 2 9

What is the primary source from which the teacher obtains courseware? (1=District or school; 2=On own from teachers, magazines, etc.; 3=Authors or writes it; 9=Not applicable) 1 2 3 9

b. IF TEACHER SELECTS COURSEWARE:
Other than content, what features does the teacher look for in selecting courseware?

What features of courseware does the respondent try to avoid?

c. Does the district/school have standard criteria for evaluating courseware?
(1=Yes; 2=No; 9=Not applicable) 1 2 9
IF YES, describe: (or append copy and note accordingly)

d. How could courseware be improved?

13. Does the respondent make use of the microcomputer for any of the following non-instructional purposes? (1=Yes; 2=No; 9=No Information)
a. Student record keeping 0 1
b. Testing students 0 1
c. Other(s)____ 0 1

14. Feedback

a. Has the respondent made any changes in methods of microcomputer use? (1=Yes; 2=No; 9=Not applicable) 1 2 9

b. IF YES, How has microcomputer use changed? (1=Changed; 2=Not changed; 9=No information)
1. Coverage of subject-matter topics 1 2 9
2. Coordination with other teaching/curricular aids 1 2 9
3. Goals for microcomputer use 1 2 9
4. Time allocated for computer use 1 2 9
5. Modes of computer use (i.e., tutorials, etc.) 1 2 9
6. Teaching strategies involving computers (i.e., matching type and content of CAI to students) 1 2 9
7. Grouping of students for computer use 1 2 9
5. Methods of selecting courseware 1 2 9
6. Rules for using microcomputers 1 2 9
7. Other(s)____ 1 2 9

c. Does the respondent monitor whether microcomputer activities are working? (1=Yes; 2=No; 9=Not applicable) 1 2 9

IF YES, describe the respondent's monitoring strategy:

TEACHERS' KNOWLEDGE/GLOBAL EVALUATIONS

Based on the respondent's discussions of uses of microcomputers in his/her instruction, and on answers to computer knowledge questions, rate each of the following:

15. Knowledge about microcomputer hardware

a. Was respondent asked question about microcomputer hardware? (1=Yes; 2=No; 9=Not applicable) 1 2 9

b. How knowledgeable does the respondent appear to be regarding microcomputer hardware? (1=Not knowledgeable; 4=Extremely knowledgeable; 9=Not applicable) 1 2 3 4 9

16. Knowledge about microcomputer courseware

    a. Was respondent asked question about microcomputer courseware? (1=Yes; 2=No; 9=Not applicable) 1 2 9

    b. How knowledgeable does the respondent appear to be regarding microcomputer courseware? (1=Not knowledgeable; 4=Extremely knowledgeable; 9=Not applicable) 1 2 3 4 9

17. How knowledgeable does the teacher appear to be with respect to the subject matter taught? (1=Not knowledgeable; 4=Extremely knowledgeable; 9=Not applicable) 1 2 3 4 9

18. Based on your discussion, how successful would you judge this teacher to be in using computers in instruction? (1=Not successful; 4=Extremely successful) 1 2 3 4 9

19. Based on your discussion, how well integrated are microcomputer activities and "regular" instruction? (1=Not integrated; 4=Highly integrated) 1 2 3 4 9

(Revised 2/11/83)

CLASSROOM OBSERVATION INSTRUMENT

School District Name ________________ School ______________________

Teacher ______________________________ Grade Level ________________

Subject Matter ______________________ Coder ______________________

PHYSICAL LAYOUT

1. Proximity of computers to teacher (circle one)

a. In classroom	1
b. In lab attached to classroom	2
c. In lab unattached to classroom	3
d. Other ________________________	9

2. How many micros are located in the class or lab? (Code 99 if not applicable) _____

3. Are the micros networked? (1=Yes, 2=No; 9=Don't know) 1 2 9

IF YES, describe how network is arranged (e.g., micro connected to hard disk drive; to mainframe computer, etc.)

4. How is the typical workstation configured?

a. Micro/monitor (M/M)	1
b. M/M + cassette tape	2
c. M/M + 1 disk drive	3
d. M/M + 2 disk drives	4
e. Other ____________________________________	9

5. Is a color monitor available? (1=Yes; 2=No; 9=Don't Know) 1 2 9

6. Is a printer available? (1=Yes; 2=No; 9=Don't know) 1 2 9

   IF YES, how many? (99=none available)

7. Are joysticks or paddles available? (1=Yes; 2=No; 9=Don't know) 1 2 9

8. Is the courseware readily accessible for use by students? (1=Yes; 2=No; 9=Don't know) 1 2 9

   Describe the location of the courseware and how to obtain it.

ORCHESTRATION OF ACTIVITY STRUCTURES

Abbreviations for Activity Structure Names

Reading Circle (RC)
Two-way Presentation (TP)
Mediated Activity (MA)
Silent Reading--Free (SF)
Games (G)
Transitions (T)
Computer (C)

Seatwork (SW)
One-way Presentation (OP)
Silent Reading--Directed (SD)
Construction (CO)
Play (P)
Housekeeping (H)
Other (O)

1. Diagram the flow of activity structures below

```
--------:--------:--------:--------:--------:--------
       10       20       30       40       50       60  (minutes)
```

2. How many different activity structures occurred during the observation period? ______

3a. Is there an adult assisting the teacher? (1=Yes; 2=No; 9=Don't know) 1 2 9

IF YES, describe the adult's function

b. Are there one or more students assisting with the operation of the microcomputers? 1=Yes; 2=No; 9=Don't know) 1 2 9

4. Is there evidence of norms for making transitions between activities? (1=Yes; 2=No; 9=Don't know) If yes, describe: 1 2 9

5. Was the flow of class activities disrupted by interruptions or any unplanned occurrences? (IF NO, go to the next section.) 1 2 9

Describe disruption and how it was handled

COMPUTER ACTIVITY

1. Typical number of students per micro ____

2. Average number of minutes a typical student or group spends at microcomputer.

3. Do the students seem to understand what is expected of them in the computer activity? (1=Yes; 2=No; 9=Don't know) 1 2 9

4. Is the teacher attending to what the students are doing at computer (e.g., controlling unruly behavior, monitoring work at machines)? 1 2 9

5. To what degree are the students attending to the computer task? (1=Not at all; 4=Completely) 1 2 3 4

6. What types of computer-based instruction is being used? (1=used; 2=not used; 9=Don't know)
   - a. Drill and practice 1 2 9
   - b. Tutorial 1 2 9
   - c. Simulation 1 2 9
   - d. Tests 1 2 9
   - e. Games 1 2 9
   - f. Other ________________________ 1 2 9

7. What is the subject matter of computer-based instruction? (1=included; 2=not included; 9=Don't know)

   - a. math 1 2 9
   - b. biology 1 2 9
   - c. chemistry 1 2 9
   - d. physics 1 2 9
   - e. general science 1 2 9
   - f. other ________________________ 1 2 9

8. Does the observed computer activity overlap at all with what is being taught in other class activities during the observation period? (1=yes; 2=No; 9=Don't know) 1 2 9

COURSEWARE EVALUATION FORM

Instructions: Choose a typical student using a piece of courseware and observe him or her. Based on your observation, judge the accuracy of the following descriptions of the courseware.

If the description is not accurate, circle "1".
If the description is partly accurate, circle "2"
If the description is fairly accurate, circle "3".

Please rate all descriptions.

Name of courseware rated: ____________________

DESCRIPTION	Not Accurate	Partly Accurate	Fairly Accurate
1. Organizes material reasonably.	1	2	3
2. Branches to an effective help sequence	1	2	3
3. Contains language appropriate to audience	1	2	3
4. Contains appropriate "frame" size (i.e., neither too small nor large	1	2	3
5. Provides informative feedback	1	2	3
6. Contains material that varies in difficulty	1	2	3
7. Boring to use	1	2	3
8. Provides learner with choices of path within the learning module	1	2	3
9. Keeps learner active	1	2	3
10. Holds learner's attention	1	2	3
11. Easy to use	1	2	3
12. Uses graphics in pedagogically sound way	1	2	3
13. Provides pedagogically sound text placement	1	2	3
14. Contains idiosyncratic symbols	1	2	3
15. Difficult to crash	1	2	3
16. Can be restarted at point of stoppage	1	2	3

9. Judging from student error rates, if possible, how difficult is the CAI material for the students? (1=Not difficult; 4=very difficult; 9=Can't rate) 1 2 3 4 9

10. To what extent do computer and other classroom activities interfere with each other? (1=Not at all; 4=Very much) 1 2 3 4

11. Are all students using the same courseware, or does courseware differ among students or groups of students? (1=Same courseware; 2=Different courseware; 9=Not applicable) 1 2 9

Describe any observed correspondence between type and content of CAI and student characteristics (e.g., ability)

GENERAL COMMENTS/DESCRIPTIONS REGARDING COMPUTER ACTIVITIES

APPENDIX B:
METHODOLOGICAL CONSIDERATIONS

CLUSTER ANALYSIS AND CLUSTER INTERPRETATIONS

Presented below are the methodological details of the cluster analysis and of the interpretations of the clusters that emerged.

Cluster Analysis

The cluster analysis was carried out on certain of the indicators of our definition of successful use. Specifically, we selected six of the 16 variables in Table 3.2 representing instructional goals (Mastery, Unique Goal), ongoing curriculum (Coordination), computer-based instructional activities (Group Size, Number of Modes), and feedback (Change Use). This was done for three reasons. First, they represented the dimensions of instructional computer use. Second, they did not rely on summary judgments of success made by teachers or interviewers. Third, the remaining variables could be used to test whether our initial interpretations of the clusters held up for a set of conceptually related variables not included in the original cluster analysis. That is, the clusters should not only differ significantly on the six variables used to form them, they should also differ in meaningful ways on a number of the other indicators of success.

A two-stage cluster analysis was conducted on the six variables following Kettenring, Rogers, Smith, and Warner (1976), ultimately yielding four interpretable clusters. The first stage used Ward's procedure (see Hartigan, 1975) with standardized scores on the six variables. This procedure minimizes the within-cluster variance among teachers on the six variables while maximizing the between-cluster (centroid) variance. In this way, the 60 teachers were placed into 13 well-defined clusters. The results of Ward's procedure were verified with an average-link algorithm (see Hartigan, 1975). The 13 clusters were reduced to four with Johnson's (1967) hierarchical clustering method using the single-link criterion. In this way, the 13 clusters were merged, one at a time, into the final four clusters. The results of the single-link method were verified with an average-link method.

If the cluster analysis were successful, the clusters should differ significantly on each variable. We used a one-way analysis of variance to statistically test for differences among the cluster means on each of the six variables, followed by pairwise post-hoc comparisons using Tukey's method. The pattern of differences among the four clusters enabled us to make a preliminary interpretation of the clusters. Next, we compared the clusters statistically on the remaining attributes to validate the preliminary interpretation of the variables. Finally, we identified individual teachers who were prototypical of each cluster and described their instructional uses of microcomputers based on interviews and observations (see Section III).

Interpretation of the Clusters

Table B-1 presents the cluster means for each of the six variables entering the cluster analysis. As expected, the clusters differed significantly on each variable ($\alpha=0.05$). Teachers in clusters 1, 3, and 4 tended to coordinate classroom activities (e.g., lectures; readings from texts) with microcomputer activities to a greater extent than did teachers in cluster 2; teachers in cluster 1, more than teachers in cluster 3. Teachers in cluster 1 (and 4) also used microcomputers to help students master basic skills to a greater extent than did group 2 (or 3). The use of the microcomputer as an activity for students in its own right, in addition to being an instructional tool (Unique Goal), distinguished teachers in cluster 1 from the other teachers, and teachers in cluster 2 from clusters 3 and 4. Teachers in cluster 3 unanimously grouped two or more students for computer use while those in cluster 4 did not; teachers in clusters 1 and 2 fell in between. The methods of microcomputer use tended not to change for teachers in cluster 4, while three-fourths of the teachers in the other three clusters modified their practices on the basis of feedback. Finally, teachers in cluster 1 tended to use a greater number of different instructional modes (e.g. drill and practice, simulation) than did teachers in the other three clusters.

Table B-1

VALIDITY OF TEACHER CLUSTERS: VARIABLES ENTERING CLUSTER ANALYSIS
[Means and (Standard Deviations)]

Variable	Cluster [a]				All (n=60)	Statistically Significant Contrasts [b]
	1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)		
Degree of coordination	3.53 (0.51) (n=17)	1.67 (0.86) (n=21)	2.50 (1.02)	3.40 (0.55)	2.58 (1.12) (n=57)	1,3,4>2 1>3
Mastery goal	2.83 (1.25)	1.78 (1.09)	2.29 (1.20)	3.00 (1.00)	2.32 (1.23)	1>2
Unique goal	0.83 (0.38)	0.43 (0.51)	0.00 (0.00)	0.00 (0.00)	0.42 (0.50)	1>2,3,4 2>3,4
Group size	1.41 (0.51) (n=17)	1.23 (0.43) (n=22)	2.00 (0.00)	1.00 (0.00) (n=4)	1.46 (0.50) (n=57)	3>1,2,4
Change use	0.78 (0.43)	0.74 (0.45)	0.79 (0.43)	0.00 (0.00)	0.70 0.46	4>1,2,3
Number of modes	3.83 (1.34)	2.57 (1.04)	2.57 (1.02)	1.80 (0.84)	2.88 1.28	1>2,3,4

[a] Cluster size is indicated in cells with missing data.

[b] Level of significance based on one-way analysis of variance was set at 0.05. Pairwise comparisons are based on Tukey's HSD test with unequal sample sizes ($\alpha=0.05$); numbers refer to cluster number. Correlations among the variables ranged form -0.16 to 0.37 with a median of 0.06 (see Table B-3).

From this pattern of differences among the four clusters, we tentatively labeled the method of microcomputer use defined by cluster 1 as "orchestration." Teachers in this cluster tended to coordinate microcomputer activities with other classroom activities; they stressed mastery of basic skills as a goal of microcomputer use but also held students' use of microcomputers as a *unique* goal. They changed instruction based on feedback, and used a variety of different modes of instruction.

The pattern of microcomputer use suggested by cluster 2 was tentatively labeled "enrichment." Teachers in this cluster were least inclined to coordinate computer-based instruction with other classroom activities or to use the microcomputer to help students master basic skills. However, they shared the goal of encouraging student microcomputer use in its own right, and they tended to assign students individually to microcomputer activities. Thus, their instructional computer use appears more ad hoc and more as an end in itself.

Cluster 3 was tentatively termed "grouping." These teachers were distinguished by their grouping decisions--they provided computer-based instruction to students in groups of two or more. Otherwise, their instructional uses are not especially notable; they are at the mean of the four clusters on coordination of microcomputer activities and emphasis of mastery of basic skills.

Cluster 4 was tentatively labeled "drill and practice." These teachers tended to coordinate computer activities with class activities, stress mastery of basic skills while holding no unique goals for microcomputer use, and to view microcomputer-based learning as an activity for individual students. They tended *not* to change their instructional practices or use multiple instructional modes.

These interpretations are clearly tentative. They can be further developed or modified, however, by examining the pattern of results on those variables related to "successful" microcomputer use that did not enter into the cluster analysis. Table B-2 provides the pertinent data.

Cluster 1 is distinguished from the other clusters by the degree to which the microcomputer was used for instruction and the importance placed on cognitive goals for instructional microcomputer use. In conjunction with the findings from Table B-1, the "orchestration" label continues to fit this group of teachers. Furthermore, the summary judgments of success and integration support this interpretation--teachers in cluster 1 were viewed by the interviewers as more successful and their instruction more integrated than that of the teachers in the other clusters.

Table B-2

VALIDITY OF TEACHER CLUSTERS: VARIABLES FROM
ADDITIONAL INDICATORS OF SUCCESS
[Means and (Standard Deviations)]

Variable	Cluster [a]				All (n=60)	Statistically Significant Contrasts [b]
	1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)		
Other subjects	0.56 (0.51)	0.74 (0.45)	0.29 (0.47)	0.0 (0.0)	0.52 (0.50)	2>3,4
Instructional use	3.33 (0.84)	2.45 (0.69) (n=20)	2.64 (0.74)	3.60 (0.89)	2.88 (0.87) (n=57)	2<1,4
Cognitive goal	2.89 (1.37)	2.39 (1.34)	2.86 (0.86)	1.20 (0.45)	2.55 (1.27)	1>4
Motivation goal	2.78 (1.48)	1.91 (1.24)	2.29 (1.38)	2.20 (1.30)	2.28 (1.37)	ns
Management goal	1.33 (0.97)	1.22 (0.74)	1.21 (0.80)	1.00 (0.00)	1.23 (0.79)	ns
Perceived success	3.33 (0.59)	3.33 (0.77) (n=18)	2.80 (0.92) (n=10)	3.20 (1.10)	3.22 (0.78)	ns
Success rating	3.22 (0.65)	2.73 (0.63) (n=22)	2.64 (0.84)	2.40 (0.89)	2.78 (0.83) (n=59)	[c]
Perceived integration	3.27 (0.67)	2.50 (0.71) (n=18)	2.80 (0.63) (n=10)	4.00 (0.00) (n=4)	2.47 (1.32) (n=50)	2<1,4 3<4
Integration rating	3.44 (0.70)	2.35 (0.88) (n=20)	2.33 (0.98) (n=12)	3.40 (0.89)	2.80 (0.99) (n=55)	1>2,3

Table B-2

VALIDITY OF TEACHER CLUSTERS: VARIABLES FROM ADDITIONAL INDICATORS OF SUCCESS
[Means and (Standard Deviations)]
(continued)

Variable	Cluster [a] 1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	All (n=60)	Statistically Significant Contrasts [b]
Equal time	0.59 (0.51) (n=17)	0.91 (0.29) (n=22)	0.69 (0.48) (n=13)	0.75 (0.50) (n=4)	0.75 (0.44) (n=56)	ns

[a] Cluster size is indicated in cells with missing data.

[b] Level of significance, based on one-way analysis of variance, was α=0.05. Pairwise comparisons are based on Tukey's HSD test with unequal sample sizes (α=0.05); numbers refer to cluster number. Correlations among the variables ranged from -0.29 to 0.69 with a median of 0.16. Statistically significant correlations were found among instructional use, success, perceived integration, and integration (α=0.05, see Table B-4).

[c] Statistically significant differences between clusters but, due to loss of power due to unequal sample size, no pairwise differences using Tukey's test were found. (For a discussion of the relation between the analysis of variance and Tukey's test, see Shavelson, 1981).

The "enrichment" label applied to Cluster 2 receives some support. These teachers were least inclined to try to achieve broad coverage of the subject matter with the microcomputer (Instructional Use in Table B-2); indeed, they are most likely to try to bring the microcomputer into other facets of instruction such as word-processing or instruction in other subject-matter areas. Thus, the microcomputer seems to be used to enrich academic instruction, within an overall goal of providing students with opportunities to become familiar with the microcomputer.

The interpretation of cluster 3 as "grouping" was modified to "adjunct instruction" based on data in Table B-2. These teachers tended to confine microcomputer use to the given subject-matter areas and to stress acquisition of conceptual knowledge. But their microcomputer use seems catch-as-catch-can. Unlike teachers in cluster 2 who try to use the microcomputer to provide a wide range, even if a limited amount, of instruction, the approach of the cluster 3 teachers appears to be to selectively augment certain lessons, stressing conceptual knowledge, with what little courseware might be available.

Finally, the interpretation of cluster 4 as a group of teachers stressing "drill and practice" receives additional support. These teachers tended to use microcomputers extensively to help students master basic skills, but not to help them acquire conceptual knowledge. Moreover, they tended to use microcomputers solely in one subject matter (math or science).

ADDITIONAL STATISTICS

Presented below are tables of statistics that provide additional details on the statistical analyses carried out.

Table B-3

CORRELATIONS AMONG VARIABLES ENTERING THE CLUSTER ANALYSIS

	1	2	3	4	5	6
1. Coordination	--					
2. Mastery	.27	--				
3. Micro-goal	.07	.00	--			
4. Group size	.00	-.16	.08	--		
5. Change use	-.14	-.01	.04	.10	--	
6. Modes	.17	.10	.37	.01	.20	--

Table B-4

CORRELATIONS AMONG VARIABLES FROM DEFINITION OF INSTRUCTIONAL MICROCOMPUTER USE

	1	2	3	4	5	6	7	8	9
1. Other Subjects (n=60)	-								
2. Instructional use (n=57)	.23	-							
3. Cognitive (n=60)	.00	.17	-						
4. Motivation (n=60)	.12	.13	.06	-					
5. Management (n=60)	-.29	.12	-.01	.20	-				
6. Perceived success (n=51)	-.07	.39	-.07	-.08	.14	-			
7. Success (n=59)	-.05	.50*	.19	.37	.27	.22	-		
8. Perceived integration (n=50)	.36	.59*	.18	.14	.05	.32	.32	-	
9. Integration (n=55)	.10	.68*	.11	.15	.16	.22	.58*	.68	-
10. Equal time	-.21	.01	-.13	-.09	-.13	.07	.15	.15	.10

*For n=60 and 10 variables, r=0.47 (α=.05); for n=50 and 10 variables, r=0.51 (α=.05)

Table B-5

CORRELATIONS AMONG INSTRUCTIONAL VARIABLES

Time Allocation and Attention

	1	2	3
1. Aid (n=37)	--		
2. Student Time (n=58)	-.04	--	
3. Student Attention (n=52)	-.14	.03	--

Modes of Use

	1	2	3	4	5
1. Drill (n=60)	--				
2. Tutorial (n=60)	.02	--			
3. Simulation (n=60)	-.02	.22	--		
4. Microworld (n=60)	-.11	.04	.07	--	
5. Games (n=60)	.12	.02	.32	.04	--

Rules for Microcomputer Use

	1	2	3	4	5
1. Games (n=60)	--				
2. Talking (n=60)	-.05	--			
3. Operation (n=60)	.06	.11	--		
4. Access (n=60)	.01	.01	.18	--	
5. Time (n=60)	-.02	.03	.06	.69*	--

Assignment Strategies

	1	2	3	4	5
1. Mode-match (n=60)	--				
2. Content-match (n=60)	.13	--			
3. Ability (n=60)	.07	.26	--		
4. Computer knowledge (n=60)	-.13	-.07	-.07	--	
5. Other (n=60)	.26	-.19	-.34	-.17	--

Courseware Acquisition

	1	2	3	4
1. Participates (n=57)	--			
2. School (n=51)	-.08	--		
3. Teacher (n=55)	.81*	.24	--	
4. Write (n=41)	.39	-.42	.06	--

*Statistically significant at $\alpha=0.05$ for the number of cases and number of variables.

Table B-6

COMPARISON OF TEACHER CLUSTERS AS TO DISTRICT AND SCHOOL CONTEXT
[Means and (Standard Deviations)]

Variable	Cluster 1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	All (n=60)	Statistical Significance
District Context						
Routine support of micros	0.89 (0.32)	0.74 (0.45)	0.86 (0.36)	0.40 (0.55)	0.78 (0.42)	ns
Implementation	0.33 (0.49)	0.26 (0.45)	0.07 (0.27)	0.20 (0.45)	0.23 (0.43)	ns
Funding	0.33 (0.46)	0.35 (0.49)	0.29 (0.47)	0.20 (0.45)	0.32 (0.47)	ns
School Context						
Resources	0.67 (0.49)	0.43 (0.51)	0.57 (0.51)	0.40 (0.55)	0.53 (0.50)	ns
Incentives	0.72 (0.46)	0.48 (0.51)	0.64 (0.50)	0.80 (0.45)	0.62 (0.49)	ns
Release time	0.55 (0.51)	0.30 (0.47)	0.43 (0.51)	0.60 (0.55)	0.43 (0.50)	ns
Pay	0.11 (0.32)	0.09 (0.29)	0.21 (0.43)	0.20 (0.45)	0.13 (0.34)	ns
Home	0.22 (0.43)	0.09 (0.29)	0.14 (0.36)	0.20 (0.45)	0.15 (0.36)	ns
Recognition	0.17 (0.38)	0.22 (0.42)	0.07 (0.27)	0.40 (0.55)	0.18 (0.39)	ns
Physical location	0.61 (0.50)	0.35 (0.49)	0.29 (0.47)	0.40 (0.55)	0.42 (0.50)	ns
Number of micros in school	11.94 (12.29)	11.62 (9.17)	10.62 (8.93)	20.00 (7.87)	12.23 (10.18)	ns

Table B-7

CORRELATIONS AMONG SETS OF CONTEXT VARIABLES

(a) District Variables

	1	2	3
1. Routine support (n=60)	-		
2. Implementation (n=60)	-.38*	-	
3. Funding (n=60)	.10	-.25*	-

(b) School Variables

	1	2	3	4	5	6	7	8
1. Resources (n=60)	-							
2. Incentives (n=60)	.15	-						
3. Release time (n=60)	-.06	.55*	-					
4. Pay (n=60)	.07	.31	-.05	-				
5. Home (n=60)	.30	.14	.01	-.16	-			
6. Recognition (n=60)	-.07	.37	.11	-.06	-.08	-		
7. Location (n=60)	.18	.25	.08	.07	-.07	.12	-	
8. Number (n=57)	-.34	-.09	.05	.09	-.09	.05	.11	-

(c) Classroom Variables

	1	2	3	4	5
1. Number micros (n=57)	-				
2. Proximity (n=54)	.72*	-			
3. Grade level (n=60)	.20	.07	-		
4. Percent minority (n=60)	.02	.01	-.10	-	
5. Ability level (n=60)	-.19	-.16	.12	-.56*	-

*Statistically significant at $\alpha=.05$ for number of cases and number of variables within the set.

APPENDIX C:
MODES OF MICROCOMPUTER-BASED INSTRUCTION

TYPES OF SOFTWARE

Three types of software are used in classrooms: instructional, applications, and utility. *Instructional* software--often called courseware--is the term applied to computer programs designed to present material about or provide practice with some specific topic or subject area. This section is concerned mostly with courseware and its various forms: drill and practice; instructional games; tutorials; simulations; data bases; and special languages such as Logo.

Applications software includes programs designed for a well-defined, but possibly very general, purpose. Word processing and data base management systems are examples of applications software.

Utility software refers to programs designed to carry out some specialized function for the user. These may be self-standing programs or they may be designed to work in conjunction with other procedures or programs. A simple record-keeping program is an example of a utility; it can be a generic program or a set of procedures within another program. Thus, an instructional program could contain utility programs. We will discuss certain utility programs--facilities for testing and keeping records on students, and software that can control instruments in laboratory experiments.

Other ways of grouping and labeling software exist (see, e.g., Licklidder, 1979; Loop and Christensen, 1982; Westrom, 1983; Salisbury, 1971; Kearsley et al., 1983a,b, for alternatives to the above distinctions). Perhaps the most familiar characterization is the distinction between Computer-assisted instruction (CAI) and Computer-managed instruction (CMI). CAI roughly corresponds to what we have termed courseware (although some distinguish drill and practice from CAI).

CMI refers to "an overall system for educational management in which detailed student information, complete curriculum data and information on available resources are integrated to develop individualized programs of instruction, revise curriculum content, provide for necessary counseling and guidance, and facilitate optimal educational resource management" (Salisbury, 1971). Gradually, CMI has come to mean nothing more than a system that keeps track of student errors and suggests additional work to deal with difficulties or weak points. We do not discuss CMI systems as such. Instead, we discuss record-keeping and management facilities, which may be part of a larger computer program.

TYPES OF COURSEWARE

Drill and Practice

Drill and practice is characterized by the repeated presentation of problems of a particular type. (See, e.g., Westrom, 1983; Licklidder, 1979). Presentation order and rate may be predetermined and fixed, or variable and dependent on the learner's performance. Analysis of the student's answer is possible, but is generally limited to a search for the correct answer and sometimes a small number of likely and easily identifiable errors. If provided, remediation is usually in the form of additional problems of the type missed. Explicit discussion and resolution of the difficulties are seldom provided in drill and practice programs.[1]

Drill and practice is the most common use of microcomputers in schools--after computer literacy and instruction in programming; it is the most common subject matter based use of the computer. Fifty-nine percent of the elementary schools responding to a national survey said they used drill and practice "regularly" or "extensively." About half as many (31%) of the secondary schools so responded (School Uses of Microcomputers, 1983, #1).

Drill and practice can provide supplementary practice in the use and appliction of certain skills or concepts. This presumes that the skill has already been learned or is currently being covered in class.

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[1] This discussion refers to programs on microcomputers. There are drill and practice programs with extensive remediation sequences on large computer systems--for example, TICCIT (Merrill, 1980; see also Chambers and Sprecher, 1980). A nice example of the range of facilities and approaches in drill and practice programs may be found in Williamson and Monroe (1983).

The format of a drill and practice session--generally nothing other than the presentation of a problem and evaluation of the student's responses--makes it unsuitable for learning *how* to solve problems of the given type. The practice provided by the program helps make the skill more automatic and thus more independent of higher level cognitive processes. Automaticity is important because by "freeing attention" from the mundane steps performed by a skill--e.g., small scale multiplication--the person is also in a better position to notice relationships and outcomes. Insights gained in such cases may serve as "tricks" or guides for estimating or evaluating the plausibility of a problem solution.

What can a teacher reasonably expect from a drill and practice program? At the minimum, a drill and practice program serves as an electronic workbook: presenting problems in a given sequence, determining whether the answer is correct, giving feedback (usually the correct answer), and going on. This is what the teacher or an aide does with a workbook page. The difference is that the computer does it almost instantaneously and with complete patience. Moreover, the computer tends to hold the student's attention to a greater extent than a workbook. Thus, to the extent that workbooks serve a valuable function in the goals of a particular teacher, drill and practice materials would have similar uses, with the consequence of increasing effective time on task. The immediate feedback *can* be useful in facilitiating learning. However, with some drill and practice materials, students may learn simply to press [return] in order to get the correct answer. They may then merely memorize or copy the answer, anticipating the next appearance of the same problem.

More sophisticated drill and practice courseware can do complex error analysis and remediation (in the form of additional problems or a sample solution); it can record performance, possibly acting automatically on the basis of the learner's performance. Such programs let the learner use his or her (very) limited time at the keyboard more effectively. A program that determines the types of difficulties someone is having and then presents problems of that type to remediate these difficulties will provide a more useful and effective set of problems to the user than a program that simply selects problems independently of the user's answers. Moreover, such a program also informs the student about his or her difficulties.

Numerous studies have examined the effectiveness of such instructional programs (usually drill and practice materials), and several reviews exist (e.g., Edwards et al., 1975; Kulik et al., 1980; Vinsonhaler and Bass, 1972).

Despite the number of such studies, methodologically sound results are not very common (Kulik et al., 1980). Nevertheless, results of the research generally indicate that drill and practice produces gains in ability when used to supplement other teaching.

A recently completed longitudinal study supports these conclusions from earlier research. Ragosta (1983) followed elementary students working with mathematics or with reading and language arts drill-and-practice materials over a 4-year period. She found that all of the CAI groups improved. For the math materials, the improvement of experimental over control students increased with each year of math drill and practice. Results for non-math students were less clear-cut, however.

Thus, drill and practice may improve student's performance by effectively supplementing other teaching. These conclusions must be qualified, however. First, other instructional supplements (e.g., content related activities) may also improve students' performance in some instances (Sherman, 1983). Second, the effectiveness of the particular drill and practice materials used in the research does not imply that all drill and practice programs will improve students' performance. The research used particular programs, not randomly selected materials. Therefore, the results cannot simply be generalized to all drill and practice materials. The quality of the courseware must also be taken into account in deciding whether particular programs are likely to improve students' performance in a topic area.

Instructional Games

Games as rewards: Traditionally, drill and practice courseware has had a rather standard and straightforward format. More recently, courseware developers have taken increasing cognizance and advantage of the motivational possibilities of games. Malone (1981) found that the motivating aspects in games were fantasy, curiosity, and challenge.

There is good reason to expect students to be more motivated to perform if the drill and practice includes a game. For example, Weusi-Puryear (1975) let students make a move in a tic-tac-toe game when they correctly answered arithmetic problems in a drill and practice program; they lost a move for an incorrect answer. Their achievement was higher than that of students in a control group. They answered more questions correctly, and required fewer problems to reach criterion in their performance. In this case, the game was used as a reward for good performance on standard drill and practice problems. Despite the intuitive plausibility of using games to motivate subject matter learning, and the existence of case studies in journals such as *The Mathematics Teacher* and *Electronic Learning*, little systematic research exists on the issue, and very little is known about the psychological processes by which motivational games influence subject-matter mastery.

Games as skill-independent context: A second use of games is in the drill and practice context itself. Here there are two possibilities. First, the game component may be independent of the skills to be taught; it simply provides a context for the drill and practice. An example is "Meteor Multiplication" by Milliken. In this program, the learner is to shoot meteors containing the correct answers to multiplication problems before the meteors land on the space station. The game requires motoric skill. Mathematical ability can easily become secondary, with students practicing fast shooting as a means of avoiding the need to multiply. Performance in such games need not imply anything about the student's understanding, however. The performances of a motorically skilled student with little understanding of the material and a clumsy player with a sound understanding of the content may not be distinguishable at the observational level.

Games as integral context: The second possibility is that the subject matter skill to be learned is also needed to play the game well (e.g., Dugdale, 1983; Segall, 1982)--i.e., game skill is integral to mastery of the subject matter. For example, the game Green Globs (Dugdale, 1983) presents to the student coordinate axes containing 13 green globs at random locations. Globs are destroyed by entering equations that pass through the globs (points). The goal is to destroy all 13 globs with as few equations as possible. The direction and magnitude of errors can provide additional information for selecting subsequent equations. Many of these games, then, permit the student considerable exploration and variation, because they have only an overall goal, and part of the task is to determine a path to that goal. Performance in the game provides the learners with feedback about their command of the skill to be learned. An important consideration in games concerns rule difficulty, and we make this our first recommendation.

Recommendation C1: Game rules should be very simple in comparison to the skills being taught.

Instructional games also differ as to opponent--the computer, another learner, or the problem itself (e.g., Green Globs). The type of program involved will determine the utility of the courseware for a particular class configuration. For example, Green Globs would be more appropriate to use in a group context--because a solution path can be formulated by group consensus--than would Meteor Multiplication, which involves the motoric skills of one person at a time. Research (e.g., Inbar, 1966) indicates there may be appropriate group sizes for particular game situations. Beyond this size, interaction actually decreases and the game has much less impact on the players.

Teachers also need to be aware of changes in motivation likely to result from the use of instructional games. If the game is a reward for doing the work, the game--not the skill--will be motivational. The skill to be learned is itself motivational in "intrinsic models," such as Green Globs, because playing the game is practicing the skill and, to the extent the learner wants to play the game, he or she wants to practice the skill. Because intrinsic models represent such strong motivators they are a recommended approach to instructional games.

Recommendation C2: Where possible, intrinsic models should be the instructional game format used in courseware, because of the motivational advantages of this form.

Tutorial

Tutorial programs are intended to teach as well as provide practice in a given content area (see e.g., Dennis, 1979a, for a brief discussion of tutorials). Unlike drill and practice programs, tutorials need not require constant activity by the user; however, active learning and interaction with the program are almost universally encouraged. The sequence of the material in a tutorial is crucial, since new information almost always depends on earlier materials. Consequently, it is virtually impossible for someone unfamiliar with a topic to write a tutorial on that topic.

At one extreme the tutorial is nothing more than an electronic lecture. It is not uncommon for authors who know the subject matter, but who have minimal programming skills, to try their hand at writing programs. In a tutorial format, the result is often a program that simply presents one screenful of information after another. The user is passive, except for an occasional [Return] to move to the next screen. There is no way to determine whether the learner is attending to the tutorial in such cases.

In a "quasi-interactive" tutorial the student is more active and may have to answer numerous questions about the material. Nevertheless, the interaction is more appearance than fact. The answers required may simply be restatements of something presented in the text on the screen; or they may be selections from multiple choices that could be answered by a clever reader with no real understanding of the material. This is likely to occur if the questions do not require the learner to apply the skills or principles in situations calling for a sound grasp of the material.

At the other extreme from an electronic lecture, a tutorial can take the form of a Socratic dialogue (see, e.g., Bork, 1981; Carbonell, 1970). Well-designed dialogues will require frequent and varied interaction by the learner, including exploration or experimentation, selection by various means, and free input. In a dialogue, learners are constantly required to demonstrate they understand the material before anything new is presented. If properly designed, the dialogue will respond to most free input in an appropriate manner, and will be noncommittal when it does not understand the learner's answer. The program should recognize difficulties with high accuracy, and should provide the needed help sequences. The extent to which help will be effective depends on the program's ability to identify a student's particular difficulty. Therefore, it is necessary to guard against people who guess correctly. "Open-ended" questions make it much more difficult than multiple-choice questions to answer correctly without understanding the material.

Open-ended questions, however, are much more difficult to analyze (Loop and Christenson, 1982; Westrom, 1983). Only someone extremely knowledgeable about the material, and sensitive to students' conceptions and difficulties will be able to anticipate and identify the forms the errors will take. Very few people will be both subject matter and programming experts; a high quality tutorial, such as a dialogue, demands both types of expertise. The next recommendation is a consequence of these considerations.

Recommendation C3: Tutorial dialogues should be developed by a group rather than by individuals.

Because of their complexity, dialogues generally use a considerable amount of computer memory. Hardware needed for sophisticated tutorials, such as dialogues, is only starting to enter the schools in sizeable quantities. For this, and for reasons related to developments in programming methods, tutorials in the form of dialogues are much more recent developments than drill and practice, or even games.

Simulations

For most people, the term simulation calls to mind something like a flight simulator, or perhaps "games" such as Lemonade. These are, indeed, simulations, since they represent particular aspects of phenomena and since actions on the player's part will have consequences within the context of the simulation. For example, landing at too steep an angle may result in a crash, and an abrupt ending to the player's flying career. Simulation programs produce outcomes or information about a phenomenon on the basis of certain information (parameter values) provided or actions taken by the user in a particular situation. Computer simulations are a means of demonstrating phenomena of interest in a convenient manner: one can carry out experiments or activities that would ordinarily be too dangerous or expensive, and therefore impossible, to do. Simulations have long been used in educational settings (see Boocock and Schild, 1968, for examples), particularly in business and management contexts.

Dennis (1979b) distinguished among 3 general classes of simulations, differing in the learning outcomes emphasized:

1) *replicable performance*;
2) information retrieval; and
3) encounter.

In replicable performance simulations, the learner is expected eventually to master the logic behind, and the execution of necessary procedures in, a situation, be the situation replicating a scientific experiment or "flying" an airplane.

In information retrieval simulations the learner is faced with a phenomenon which will yield (generally quantitative) data under appropriate inquiry. The learner's task is to determine the underlying laws or relationships. For example, students might ask for data about various generations of offspring and mixes of characteristics of a plant, in order to determine the laws of Mendelian genetics. In replicable performance, the emphasis is on a performance; in information retrieval, the goal is the discovery of operative principles.

In encounter simulations, "the learning outcome is the 'experiencing' of a situation. One is expected to become aware of (perhaps) vaguely defined possibilities or probabilities of the situation. The learning goal is awareness of variability among the consequences, and procedures for assessing the magnitude of this variability" (Dennis, 1979b). Encounter simulations are most useful for nondeterministic situations, or those where the causal principles are not fully understood. Social or business situations requiring role-playing or decisionmaking on the learner's part are areas where encounter simulations are particularly applicable.

Simulations vary considerably with respect to the manner and extent of the learner's interaction with the program. At one extreme, the simulation is nothing more than a data base: it prompts the learner for values of various parameters, then draws tables or graphs which the learner must copy and organize in the manner required by the assignment. The learner must do the work that the computer can do most easily, i.e., tabling and storing data, and computing various pieces of information about the data.

In highly interactive simulations, learners must constantly make decisions or answer questions about their actions. The manner in which the results of their actions are presented can still vary considerably, however. This may range from iconic or pictorial to abstract or quantitative information and feedback.

Each type of simulation is useful in particular situations. Determining the particular advantages and disadvantages of each for a specific class is the teachers' task. Different sets of skills are involved in the problem-solving repertoires required for the various types of simulations. For example, even a minimally interactive information retrieval simulation can be very useful to teachers trying to give their classes practice at reading, transforming, and organizing information. On the other hand, teachers trying to develop students' decisionmaking skills could use a highly interactive, perhaps group-oriented, encounter simulation to great effect.

Simulations are useful for learning in a broad range of content areas and situations. As a variation on standard information presentation formats, simulations can help develop different cognitive skills from other learning methods--as well as teaching about the topic of the simulation. Bewley et al. (1975) argued that the symbolic nature of simulations (which are abstract models of phenomena) facilitate the development of skills for deriving the necessary information from the simulation.

Research on the effects of computer simulations generally indicates a positive effect (see, e.g., Edwards et al., 1975; Kemmis, 1977). The general conclusion seems to be that simulations are most clearly effective as a supplement to other instruction; when simulations are substituted for other instruction, effects are much less clear (see, Edwards et al., 1975).

Simulations often result in important incidental or unintended learning of skills or insights not explicitly included in the simulation. There may also be subtle consequences of simulations that are as yet unrecognized--particularly relating to the extent to which the information in the simulation is completely observed. Simulation developers, as well as teachers, need to be aware of the multiple cognitive levels at which simulations may affect reasoning and understanding.

Simulations can also be opportunities for students to get rid of misconceptions and misunderstandings of phenomena. By exploring and testing their beliefs about a situation, students can often determine erroneous expectations. Ideally, the students will be able to correct their misconceptions once identified. Perhaps more importantly, such mistakes can be made in a non-judgmental context: there is no one waiting to pounce on an incorrect answer.

Another type of courseware, closely related to simulations, deserves mention here. Microworlds are "cybernetic environment[s] in which elements can be combined according to given rules. Students learn about the rules and their consequences while mastering a variety of problem solving techniques as they explore the microworld" (Tinker, 1983, pp. 36-37). The explicit goal in the microworld is to find out about the causal relationships and structural principles at work in the microworld; implicitly, exploration and experimentation techniques and possibly other operations are being reinforced, in addition to the content being communicated.

One particular attraction of simulations is their utility in various subject areas--from programs like Oregon Trail in social studies to models of gravity on planets different from earth in physics. To further facilitate the creation and use of simulations, Roberts and her co-workers have developed Dynamo, a language designed for the development of simulations and models of phenomena (see Roberts et al., 1983). Simulations are likely to play a considerable role in computer based learning, because of their general applicability, and also because pedagogically, they help instantiate directly the laws underlying topics being studied, as opposed to simply stating facts and relationships that the learner must then memorize.

Despite the tremendous potential, simulations can actually confuse more than teach. Simulations demand much more interpretation and decisionmaking by the learner than other types of courseware. An adequate context, generally provided by supplementary notes or teachers' guides, is therefore indispensable. The teacher's role is particularly important and subtle in simulations, because much of the information in a simulation must be discovered or constructed by the learner. The teacher may need to guide the students to learn the desired information or principles, but to do this without simply giving the students the information. From the particular importance of accompanying materials with simulations we derive our next recommendation.

Recommendation C4: Supplementary materials--notes to involve and guide teachers and students, thought questions, clear instructions and documentation, and sample runs of the models with different parameters--are essential for simulations.

Languages

Many people argue that the reasoning processes required to specify and program the solution to a problem are very general, and that experience with such reasoning in the context of programming can have positive effects on the person's general problem solving abilities. Logo (see, e.g., Abelson and diSessa, 1981; Papert, 1980) is the best known language used for such general enrichment purposes.

Logo is a list processing language whose capabilities include graphics based on the metaphor of a turtle that can wander around a coordinate system microworld, in response to instructions from the student. Instructions can be grouped into a block or a procedure; the entire block can then be included as a single instruction in another block. Logo encourages modular specification and writing of programs. This makes it possible for users to develop useful and sound programming habits.

Papert (1980) believes Logo has revolutionary implications--because it will provide children with the tools for learning in a much more natural and creative manner. Using Logo's graphics, children can explore the possibilities and relationships of actions in the microworld. In this way, children develop geometric and other mathematical concepts; in addition, learners develop planning and abstraction skills. In fact "learning is an expected side effect" (Barr and Feigenbaum, 1982, p. 255) of the opportunity to explore or to use the computer "ad lib" (p. 225), as Logo is intended to be used. Unlike other educational situations, Logo allows children to be largely in control of their own learning.

Logo also has a very important attitudinal consequence. A child may have to revise a program several times before the instructions are appropriate for his or her goals. The child will see these faulty instructions as "bugs" to be corrected, rather than as "errors," which are to be avoided at all costs. Traditional schooling often "teaches" that an error is tantamount to "failure." In contrast, creative learning of the sort claimed for Logo suggests that bugs are a natural part of the learning experience, and the appropriate action is to modify the program until it works.

So far, however, there is a lack of sound empirical evidence demonstrating the effectiveness of Logo. There are many enthusiastic anecdotal testimonials to the effects of Logo--Papert's (1980) being among the most inspirational. These accounts of the marvelous outcomes of Logo projects are very encouraging. They are not, however, sufficient evidence of the effectiveness of Logo in producing the gains discussed above. We need to determine experimentally whether Logo produces changes in learners' reasoning and problem-solving, in their motivation, or in their manner of learning. It is arguable that standard performance measures, such as scores on standardized achievement tests, are inappropriate indicators of the effects of Logo. Nevertheless, this does not obviate systematic study. It merely means alternative measures must be found.

Consideration of the extremes possible with Logo differs from the case of other courseware. Assuming a relatively complete set of instructions in a particular implementation of Logo, the manner and quality of Logo's use depends largely on the teacher. Very commonly, teachers are constrained by the very limited amount of time children actually have at the keyboard. Logo requires adequate time for the child (or teacher) to be able to explore possibilities, and actually correct bugs. With the good intention of allowing their students to do the most in their limited time, teachers often provide the children with a listing of the instructions for drawing figures. Children thus have a drawing, but have not had the opportunity to find out for themselves how to make the drawing. Control over creation and learning in the situation is thus taken from the child. Giving children enough time at the computer may free teachers of the perceived need to give the children the answers.

Logo implementors can also help fulfill the high expectations teachers have for Logo, as suggested by our next recommendation.

Recommendation C5: Materials, for teachers and for learners, about the exploratory (as opposed to rote) uses and possibilities of Logo (much more extensive than simply drawing) are needed.

Such materials could easily be included on a disk as part of the Logo package itself. Used to its fullest (which requires giving students a great deal of time at the computer), a language like Logo can be an ideal introduction to programming and to sound problem-solving methods. This could be followed by instruction in Pascal, a sophisticated programming language that is a more useful successor to Logo than is BASIC. Logo and Pascal are both structured languages, and therefore reinforce the same problem-solving strategies. BASIC is usually not taught in a structured form; because of its usual, non-structured form, BASIC encourages starting right in with the problem solution rather than first planning the solution.

Data Bases

The computer can be used to retrieve information from a data base. Students get the information to solve a problem or to carry out a task. Through the data base, the computer is "teaching" the student facts, and the student is learning both about how to solve problems and also about the data base itself. For example, the data base could be a small almanac, and students in a science class might use it to determine the relationship between rainfall and various health indices. To use the data base for this purpose, they would have to decide what information they need, to learn how to ask for it, and to determine how to read and interpret the information provided.

A major attraction of such data bases is their amenability to a variety of uses and to customization for a particular class. With the appropriate program, teachers could simply enter the information they wished their class to have, and then let the students do their work.

Recommendation C6: Make available an option for customizing data in data base or other programs.

Laboratory Instrumentation

The computer may be used to measure or time phenomena in a laboratory, or to serve as a laboratory instrument. Programs that give the computer such capabilities are utility rather than instructional programs. They merely provide a means for obtaining or accessing certain information; the phenomenon of interest is presumably in whatever the computer is measuring or tracking.

Ford (1983) discussed uses of the computer as a laboratory instrument. The cognitive effects of such computer use are difficult to assess. On the one hand, the computer assumes much of the physical chore and distraction of measuring. This leaves the learner free to concentrate on relationships or patterns among the data.[2] On the other hand, the computer may separate learners from the phenomenon by removing the need to interact in order to measure. The learner could thus lose the understanding of the phenomenon derived from knowing how to measure it and from knowing why this yields information.

Testing and Record-Keeping

Administering on-line quizzes or tests, and tracking individuals' performances are utilities included in many courseware packages--particularly in those (e.g., SRT or Milliken Math) that cover entire courses. Tests may include questions or lists entered by the teacher into a skeleton; or they may be problems with values selected by the program. Record-keeping programs range from those that include only overall outcome (e.g., score or grade) to programs that have detailed information about the session, including values used in the problems,

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[2] In a similar manner, the calculator frees learners from the mechanical task of computing, and makes it possible for students to concentrate on when to multiply or divide rather than on doing the computation (NAS-NAE Commission, 1982). Such a view implies a reorganization of educational priorities. For example, the National Science Foundation (1983) has suggested that, since the calculator has taken over the computation, we should de-emphasize computation drill in school, and should emphasize estimation skills instead.

problems missed, sequence of problems, and answers given by students. The teacher may be able to weight and combine elements of the records in various ways to determine a final grade, or to weight test questions according to difficulty. The types of questions that can be asked in such on-line tests is limited, unless teachers are willing to read and grade the answers themselves.

An important advantage of on-line testing is that learners can get an immediate response to their answers. It is possible to build remediation into the testing sequence--to provide help and information to learners when they most need it. This, however, is rarely done; rather, most testing programs simply generate problems at random and record the number of problems presented and the percentage correct.

Recommendation C7: Consider uncommon forms of record-keeping for possible use in developing general skills such as writing.

An example of "record-keeping," with considerable potential, is an electronic notepad developed (by Helen Schwartz of Oakland University) for sorting the work done by literature students. Students write essays under pen names, and other students can leave critiques and commments anonymously, as can the teacher. Students thus get feedback about their ideas and writing in a non-threatening and novel manner; they will not be embarrassed if their work is not received well. As with Logo, fallibility becomes legitimate.

On the whole, such utilities can be very convenient, and can relieve the teacher of numerous administrative duties that consume valuable time. However, this convenience and time-saving are only realized if the teacher does not have to sit and enter the information manually.

Recommendation C8: Record-keeping programs should do record entry and modification automatically; the teacher should have to enter information manually only when entering the students' names at the start, when asking for a summary of information, or when entering information not normally collected in a class of that type.

Despite these advantages, teachers must consider the suitability of testing and record-keeping utilities for their teaching strategies and curricular emphases. This is especially important with testing programs. Convenient as such programs may be, teachers must consider whether the type of understanding demanded by the questions is what they intended to teach.

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